JUL 7 1923

Volume VII Number 3

BULLETIN

of the

American Association *of* Petroleum Geologists

MAY-JUNE
1923

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EDITOR

PUBLISHED BY THE ASSOCIATION
CHICAGO, ILLINOIS

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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FURTHER NOTES ON THE HYDRAULIC THEORY OF OIL MIGRATION AND ACCUMULATION

JOHN L. RICH
Ottawa, Kansas

Since the publication of the paper "Moving Underground Water as a Primary Cause of the Migration and Accumulation of Oil and Gas,"[1] new developments in the field and a number of questions regarding the application of the theory, which have been brought up in print and in private correspondence and discussions, make it desirable to present these further notes on the subject.

In order that those who do not have access to the original paper may readily follow this discussion, a brief résumé of the essential points of the theory is presented below.

BRIEF RÉSUMÉ OF THE HYDRAULIC THEORY

The conviction has been growing for a number of years among those who have given most thought to the manner in which oil and gas have gathered into commercial pools, that the mere buoyancy of oil and gas in water is incapable of causing extensive migration of these fluids in the sandstones and other porous rocks in which the oil pools are commonly found. Thus the "anticlinal theory" of migration and accumulation of oil and gas, in so far as it is based on the idea that the oil and gas migrate up the dip because they are lighter than the associated water, has been seriously questioned, and even abandoned by many.

[1] John L. Rich, *Econ. Geol.*, Vol. XVI, No. 6, 1921, pp. 347–71.

In amplification of the theories put forward several years ago by M. J. Munn and E. W. Shaw, the hydraulic theory here outlined may be briefly stated as follows:

1. The cause of *migration* is the movement of underground water, carrying with it oil and gas, perhaps in the form of minute globules or, in the case of the gas, perhaps, in solution.

2. *Accumulation* results from the selective segregation of the oil and gas which, on account of their buoyancy, always tend to work their way upward toward the roof of the reservoir as they are carried along by the water, and so are caught and retained in anticlinal or similar structural traps, or in places where differences in porosity cause a selective "screening" action which permits the passage of the water but holds back the oil and gas.

3. The nature of the structural trap necessary to cause accumulation depends on a balance between the force due to the rate of movement of the water which tends to keep the oil globule in continuous motion, and the force of buoyancy which tends to hold it in the highest part of any anticlinal trap which it may encounter. Where the sands are porous and the hydraulic head is strong, a sharp anticline with large closure may be necessary to retain the oil. In extreme cases, even such a structure may be inadequate to cause the component of buoyancy, which tends to arrest the oil, to overcome the force due to the moving water, which tends to carry it along. Where the sands are fine or the water movement is slow, or both, a very slight structural trap may be sufficient to arrest the movement of the oil and gas.

4. Where the water movement is especially rapid, there is not only a tendency for accumulation to be restricted to the sharpest and most effective traps, but the action may be carried still farther and cause the dissipation and removal of accumulations which have already gathered in the traps before they became affected by an increase in rate of water circulation. This removal of oil and gas accumulations by the action of moving water has been called "flushing." It is to be expected wherever altered physiographic conditions cause a change from slow to rapid water circulation.

5. Since the rocks as a whole are water-wet, it is possible for water to move slowly through very finely porous rocks into which, when wet

with water, the oil and gas cannot penetrate. Consequently, if a porous reservoir bed carrying oil pinches out and is replaced by finer materials in the direction toward which the rock fluids are moving, the oil will be screened out and left behind in the pinching end of the porous bed. This action will be the same whether the water movement is up or down the dip. This is an essential consequence of the admission that buoyancy alone is not sufficient to cause the movement of oil through reservoir rocks of the ordinary texture of the oil sands.

6. The influence of faults is important, but varies greatly with conditions. Where the water movement is *up* the regional dip, a strike fault may cause accumulation on its down-dip side by offsetting the reservoir bed and thus forming a sort of anticlinal trap. By deduction, where the water movement is *down* the regional dip, accumulation would take place on the up-dip side of the fault provided the fault cuts across a plunging anticline in such a way that the passage round its ends is not free, and provided the water movement is not rapid enough to cause flushing. In such a situation the less porous beds faulted against the reservoir rock would act as a screen or sieve, permitting the slow passage of water, but holding back the oil in the same way as where a reservoir bed pinches out down the dip. There might also be sufficient drag folding to form a small anticlinal trap along the fault. If the water movement is relatively rapid the oil accumulation would be on the protected, or down-dip side.

7. To the extent that oil migration is controlled by the movement of water, there is no theoretical reason why oil should not migrate *downward* as well as upward provided the moving water takes such a course. Undoubtedly water takes a very devious course as it seeks the lines of least resistance in its underground wanderings. Passage downward across the bedding along fault planes, joints, or other fissures must be common; and, consequently, the migration of oil to, and its accumulation in, beds below those in which it was originally formed should not be rare.

8. The movement of water in the rocks may be due to various causes. Among these may be mentioned artesian circulation, squeezing out of water during the compacting of the sediments,

deformation with its local increases and decreases of compressive stresses on the rocks; and expansion of gases generated in the rocks. Under various conditions now one, now another of these factors, or all together, may be the cause of the water movements.

According to the hydraulic theory as here outlined, the oil and gas are carried with the moving water, irrespective of the original cause of the water movement. The mode of accumulation does not depend on the cause of the movements of the rock fluids—it depends only on the rate of movement in its relation to structural and textural conditions.

FURTHER FIELD EVIDENCE FOR THE HYDRAULIC THEORY

Since the original paper was written, a number of developments in the Rocky Mountain field furnish data which appear to support the theory that hydraulic currents, rather than buoyancy, are effective in causing accumulation of oil or its retention.

San Juan Basin.—The San Juan Basin of New Mexico is a large, nearly circular artesian basin having its intake rim, for the Dakota horizon, at elevations ranging, in most places, between 6,000 and 9,000 feet above the sea. On the northwest side of the basin, the rim is much lower—about 5,000 feet. This is the lowest of the two outlet rims of the basin toward which the artesian circulation is presumably directed.

According to the hydraulic theory, as explained in the earlier paper and briefly stated above, the intake areas of this artesian basin should not be favorable for the accumulation and retention of oil on account of the strong flushing action to which their sands are doubtless subjected. The neighborhood of the low outlet rim, on the other hand, should be favorable territory because the oil which has been gathering into the sandstones throughout the extent of the basin, is being carried toward it by the artesian water.

The normal upward leakage from the reservoir sands throughout the basin should decrease the rate of flow at the outlet rim to such an extent that it would not be great enough to prevent accumulation.

Developments to date have borne out this explanation. A number of structures round the intake rims have been drilled with no results more important than the opening of fresh-water artesian

wells. Perhaps certain of the best of these structures were not tested to adequate depths—others certainly were. Until within the past few months the whole region was condemned by many geologists largely on the basis of the negative showings of these wells. More recently the Midwest Refining Company and other companies have tested structures on the outlet rim of the basin and have been rewarded by production of both oil and gas in important quantities. Furthermore, this production has been obtained, in part at least, from formations which carry fresh water in structures on the intake rim of the basin.

The Kevin-Sunburst field.—The Kevin-Sunburst field of Montana is another which seems to be best explained on the basis of the hydraulic theory. This field is situated on the northern end of the broad, low, Sweetgrass arch, in such relation to the neighboring mountains and to the outcrops of the producing formations that, while there is doubtless some artesian circulation, it must be so slow as to be unable to exert appreciable flushing action. To the south the nearest outcrops of the producing formations are 70 to 100 miles away and so related to the arch that the water entering them would find its easiest course through the two synclines on either side of the arch. On the west, the great overthrust faults of the Rocky Mountain front effectively prevent the ingress of water at levels high enough to cause flushing in the Kevin-Sunburst area.

A feature of the Kevin-Sunburst field, rather exceptional among Rocky Mountain fields, is that the productive structure has low dips. It has been an empirical rule among Rocky Mountain geologists that prospecting for oil in a structure in the Rocky Mountain region was useless unless dips were steep and closures were large. This idea finds expression even in recent publications of the United States Geological Survey. The writer has never heard a satisfactory reason advanced for this rule other than that it seemed to hold. The new field of Montana is a marked exception to the rule, as various geologists have, more or less wonderingly, pointed out.

An empirical rule such as that mentioned above must rest on some scientific basis which, once understood, would also explain seeming exceptions to the rule.

The writer believes that the scientific basis for the general lack of productiveness of Rocky Mountain structures of low dips and small closures, and the exception in the case of the Montana field, is this: The prevalent strong artesian circulation of the Rocky Mountain region, together with the open, porous nature of most of the sands, permits the flushing of all but the most pronounced structures. Only an anticline with steep dips and strong closure is ordinarily capable of trapping the oil, and of holding it against the gnawing action of the circulating water. In a region like the northern end of the Sweetgrass arch, however, where conditions do not permit strong water circulation, the oil accumulates and remains in much less pronounced structural traps.

This is a generalization which is capable of wide application and testing, and one which, if proved correct, will aid greatly in the rational development of the petroleum possibilities of the Rocky Mountain district, or wherever conditions are similar.

The Mid-Continent field.—The discussion of the application of the hydraulic theory to the Mid-Continent field of Oklahoma and Kansas in the original paper is faulty because the writer did not at the time realize the importance of the Arkansas Valley syncline as a low outlet for the Mid-Continent geosyncline and one toward which there should be a water movement, not only from the west, as described in the earlier paper, but also from the east off the Ozark uplift where many of the productive formations outcrop.

The influence of the westward flow from the Ozark uplift is clearly shown in Kansas, where the more porous formations carry fresh or brackish water to considerable depths and for long distances from the outcrops. The distribution of the oil in these more porous formations also seems to show the influence of the artesian circulation, for these formations are almost uniformly barren over the entire area where the diluting influence of the surface waters is noted. Flushing appears to be the explanation of this condition. Toward the eastern border of the productive area in the "Mississippi lime" and other formations below the Pennsylvanian, in Kansas at least, the oil is heavy and tar-like, either as a result of oxidation by meteoric waters or as a result of oxidizing rocks associated with the unconformities at those horizons.

In applying the hydraulic theory to the Mid-Continent field, therefore, the influence of the artesian circulation off the Ozark uplift should be given due weight.

THE INFLUENCE OF FAULTS

The rôle of faults in causing segregation and accumulation of oil from moving underground water depends on a number of conditions. The first requisite is that the fault should be so situated that it furnishes a suitable trap or acts as a barrier to migration. In general, faults trending parallel to the direction of water movement should have little or no effect. If a fault lies at right angles to the direction of movement, it is likely to cause accumulation of oil either on the side from which the water is moving or on the protected side away from the direction of movement, depending on the relative rate of water movement. It may also happen that, under physiographic conditions such that the water movement is slow, accumulation on both sides of the fault, or only on the exposed side, may occur; but later, when changes in physiography have caused an increase in the rate of water movement, the oil may be flushed from the exposed side of the fault, perhaps being gradually worked around to the opposite side where it remains protected from the flushing action.

To illustrate the above theory, we may suppose that a strike fault cuts across a plunging anticline at right angles to the direction of water movement as in Figure 1. If the water movement is relatively slow, oil might accumulate on the up-dip side of the fault at *A*, partly because the offsetting of the reservoir bed produces an open anticlinal trap at *A*, and partly because a filtering action of water through the less porous beds offset against the reservoir rock at the fault would tend to concentrate oil against the fault by the screening action above described. If, however, the water movement is relatively rapid, the oil could not remain at *A* because of the flushing action of the water. The only place where it could accumulate, or could remain if it had already accumulated, would be at *B*, in the area behind the fault, protected from the active water circulation.

This is the explanation proposed for oil fields like Mexia, Texas, where conditions are essentially as illustrated in Figure 1 and the

water movement is down the dip and relatively rapid, so that the exposed side of the fault has been completely flushed and it is only in the protected part of the reservoir bed behind the fault that the oil remains.

At Mexia the structure is an anticline whose west limb is cut by a fault trending about at right angles to the direction of the Gulf-ward artesian water circulation. The principal accumulation of oil is on the west slope of the anticline between its crest and the fault—in other words, in the protected zone immediately behind the fault, where it should be expected under the theory above outlined.

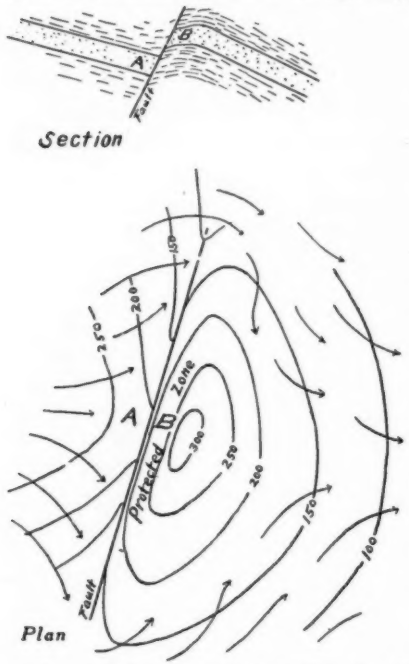

FIG. 1.—Diagram to illustrate discussion of influence of a strike fault on oil accumulation where water movement is down the dip. Arrows indicate direction of water movement.

If that theory is correct, the analyses of the water in the producing sand at Mexia should show something of the effects of the protective action of the fault as explained above. Close to the oil pool the water should retain some of the characteristics of connate sea water while on the west side of the fault, around the ends of the oil pool, and on the east side at a greater distance from the protected zone, the water should show the marked dilution with meteoric water which characterizes the water from the Woodbine sand in most places in that part of Texas.

Similar tests of the correctness of the hydraulic theory could be applied to other regions where conditions are analogous.

The distinction outlined above between the expected location of the oil pools in the cases of slow and of relatively rapid water circulation, where the water movement is down the dip, should be carefully noted. It was not sufficiently emphasized in the earlier paper, and, consequently, a number of geologists familiar with the conditions at Mexia thought that those conditions were in direct opposition to the hydraulic theory because the accumulation did not lie on the west side of the fault.

In connection with Mexia it should be pointed out that the situation of the main oil pool on the west side of the anticline is entirely out of harmony with the commonly accepted anticlinal theory that the oil moves up the dip on account of its buoyancy. Under that theory the "gathering area" for the Mexia fold is to the east and the oil accumulation should be on the crest and to the east of the crest of the anticline. It has been common to judge the value of a prospective oil structure by the size of the "gathering area" from which oil could migrate up the dip into the structure. Mexia is only one of many instances which show the fallacy of this criterion, unless, indeed, the direction of the water movement happens to be up the dip, in which case, the "gathering area" would have some significance.

It is true that the accumulation at Mexia could be explained by the action of buoyancy alone, provided the oil is shown to have come upward along the fault plane instead of having migrated up the dip of the Woodbine sand. It would seem, however, if such is the case, that oil should also be found in the sands on the west side of the fault. Another possibility is that the oil rose along the fault plane, spread out in the Woodbine sand on both sides of the fault, and was later removed from the west side by the flushing action of the artesian water.

The preceding discussion relates to the influence of faults where the movement of the artesian water is down the regional dip. Where the movement is up the dip the effects would be modified, but the same governing principles would be in effect as for down-dip movement.

On account of the variable rôle of faults under different conditions, each faulted structure will require special study in the light

of all available data on the direction and probable rate of underground water movement. In that connection water analyses from horizons which might be oil-bearing are of the greatest importance, even from unsuccessful tests, because they give information on the extent to which the original connate water has been replaced by meteoric water and thus, indirectly, on the probable strength of the underground water circulation.

Acceptance of the hydraulic theory does not lessen the importance of unsealed fault planes as channels for oil migration—it widens the scope of such possible migrations, for, if the oil is carried in the water instead of migrating on account of its buoyancy alone, it may be carried downward as well as upward along a fault plane or other fissure. Thus, whatever influence faults may have in opening channels through which oil may move from the shales out into the reservoir rocks is in no way lessened.

Recent emphasis on the importance of faulting in structures recommended for testing is likely to be carried too far, for, however beneficial to a structure faults may be in certain cases, if oil is carried in the circulating water it should be caught and held by a suitable anticlinal trap whether faulted or not. In a region, however, where water circulation is so active that flushing is dominant, a faulted structure may offer much more effective protection from the flushing action than even the sharpest anticline. Such would be the case where the relations of the fault are like those at Mexia.

RATE OF MOVEMENT OF WATER AS RELATED TO MIGRATION AND FLUSHING

For the accumulation of oil according to the hydraulic theory under discussion, it is not to be supposed that the rate of water movement is actually rapid. Darton[1] has estimated that in the Dakota sand artesian basin of South Dakota, the rate of flow in the sands does not exceed a mile or two per year. This is undoubtedly a relatively rapid flow.

The point to be borne in mind is that, inasmuch as the oil is borne along with the water, the actual rate of movement of the water

[1] Darton, N. H., *Eighteenth Ann. Rept., U. S. Geol. Survey*, Part IV (1897), p. 609.

does not enter into the question until the oil globules become too large to pass through the spaces between the sand grains. At some point, as the oil globules increase in size by coalescing, there may come a time when the rate of flow no longer suffices to overcome the friction, and accumulation begins.

When an accumulation has been formed and is subjected to a relatively rapid flow of water past it, the process of flushing is conceived of as taking place by attrition. Round the edges of the accumulated oil the water detaches minute globules of oil which are carried to the lee side of the oil pool or completely severed and carried away. Really rapid water movement is probably not necessary for this. All that is required is a movement rapid enough to overcome the delicate balance between the surface tension, which tends to prevent the detachment of globules, and the friction of the water moving past the accumulated oil.

THE GAS PROPULSION THEORY

On the basis of experimental studies, Mills[1] has recently published the theory that the propulsive force of expanding gas has been one of the most important causes for oil migration toward faults or fissures which permit the escape of the water and gas, thus setting up hydraulic currents which, together with the expanding gas escaping from solution as the pressure is lowered, effectively propel oil, even ahead of water, toward these fissures. When the pressure has been relieved or the fissures have become closed, such oil as has not already escaped remains in the neighborhood of the fissures.

Mills's theory is a significant contribution to our knowledge of the possible causes for oil migration and accumulation. It emphasizes a cause for hydraulic currents heretofore not given much recognition.

The bearing of the gas propulsion theory on the hydraulic theory here under discussion seems to be:

1. It reveals a new and effective cause for hydraulic currents.

[1] Mills, R. Van A., "Natural Gas as a Factor in Oil Migration and Accumulation in the Vicinity of Faults," *Bull. Amer. Assn. Petroleum Geologists*, Vol. VII (1923), pp. 14–21, with discussion, pp. 22–24.

2. It introduces a new factor, not hitherto recognized in connection with the hydraulic theory, namely, the effectiveness of expanding gas not only in setting up hydraulic currents, but also in entraining oil and propelling it, even ahead of water, toward the point from which gas is escaping.

3. The influence of gas propulsion and of the hydraulic currents thereby created is undoubtedly combined algebraically with that of other hydraulic currents acting at the same time as the result of other causes such as artesian head, deformation or compacting. In some instances these various currents will reinforce each other; in others they will be in opposition.

FURTHER EXPERIMENTAL STUDIES

A paper by Dodd[1] on experimental studies in the migration of oil which was in press at the time of the appearance of the writer's paper on the hydraulic theory emphasizes the inadequacy of buoyancy to cause the migration of oil in sands. In that paper it is shown that buoyancy alone causes no movement under the conditions of the experiments and, further, that the introduction of gas under static water conditions does not cause movement because the static friction which prevents the movement of the oil is also effective for the gas. It was found, however, that the oil moves readily through the sand under the influence of a hydraulic current. This movement takes place either up or down the dip but seems to be more rapid when the current is carrying the oil up the dip than when it is carrying it down.

An interesting feature brought out by these experiments was that when air or gas was introduced into the hydraulic current the migration of the oil was greatly accelerated. This seemed to be due to the action of the bubbles of air or gas in repeatedly picking up a film of oil, carrying it forward for a distance, dropping it, and then picking up another.

A fundamental bit of research which must be done before any of these experimental studies can be looked upon as pointing to reliable conclusions is the determination of the influence exerted on

[1] Dodd, Harold V., "Some Preliminary Experiments on the Migration of Oil up Low-Angle Dips," *Econ. Geol.*, Vol. XVII, No. 4 (1922), pp. 274–91.

the relative surface tensions of oil and water by gases dissolved in the oil. It may well be that oil carrying a large percentage of dissolved gas under pressure has very different surface tensional properties from the oils with which laboratory experiments are usually conducted. Certainly it is true that the resistance to movement through sand shown by oil globules under laboratory conditions is so great that, unless the globules are of microscopic size, it is a serious obstacle to the explanation of the migration of oil through the agency of buoyancy, of hydraulic currents, or otherwise. What is the fundamental factor which has been overlooked?

DISCUSSION

K. C. HEALD: As my knowledge of hydraulics is entirely academic, I asked the help of men in the Ground Water Section of the Geological Survey, and of engineers of my acquaintance in considering Mr. Rich's theory. They seemed to be in accord that flow of water through deep synclines was not to be expected. They agreed that intake would be on the high side of the basin, outlet on the low side, but they differed from Mr. Rich in that they stated the flow or currents would be peripheral, and that displacement of oil and of connate water would be by a gnawing in from the river toward the center by these peripheral currents.

J. M. DOUGLAS: I cannot understand the rapid circulation of underground water, as in every instance that I have read or heard of the movement of underground water is very slow.

MR. HOPKINS: Referring to speed of circulation of water, the French Geological Survey estimates that it has taken two thousand years for the water which emerges from the Auteil artesian well near Paris to travel about 150 miles.

JOHN L. RICH: The references of the previous speakers to the slow movement of underground water seem to indicate that they conceive of hydraulic accumulation and flushing as requiring rapid movement of the water. Such is not my conception. I look upon the oil as an integral constituent of the rock fluids and believe that it is carried along with them just as effectively when the movement is very slow as when it is relatively rapid. The process of flushing, as Mr. Heald suggests, is probably a gnawing at the edges of the oil pool and depends on a delicate balance between the tendency of the oil to move with the adjacent rock fluids, however slow that movement may be, and the static friction and surface tension of the mass of accumulated oil.

FAULTING AND PETROLEUM ACCUMULATION AT MEXIA, TEXAS

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Sun Company, Dallas, Texas

In the oil field developed at Mexia, Texas, during the past year, faulting is the dominant feature of the structure which controls the accumulation of petroleum. This paper will describe the Mexia fault,[2] and will discuss its influence upon accumulation, its relation to the regional geologic structure, and the paramount importance of faulting in the petroleum deposits of the Gulf Coastal Plain.

Widely recognized evidence of an anticline[3] in the surface beds at Mexia, together with small gas production from shallow wells led the Humphreys Oil Company under the guidance of Mr. F. Julius Fohs to undertake the exploration which finally proved the Mexia field. The discovery well was drilled near the crest of the anticline (Fig. 1), but the field as it finally developed proved to be more closely related to a fault which is situated low on the western or reverse-dip side of the anticline. The reservoir beds (Woodbine sand at the base of the Upper Cretaceous) were found to be saturated only on the upthrow (eastern) side of this fault, the oil extending back from it a relatively short distance, and barely across the axis of the anticline as displayed in the surface beds. The length of the field along the fault is nearly seven miles while the maximum width is only

[1] Grateful acknowledgment is made to Mr. D. J. Edson, Division Geologist at Mexia for the Humble Oil and Refining Company, who gathered and correlated the subsurface data upon which the accompanying text figure of the Mexia field is based.

[2] The fault at Mexia was first noted by Alexander Duessen in *Water Supply Paper 335, U. S. Geol. Survey*, which attributed the gas production from the shallow sands to the influence of this fault.

[3] George C. Matson, in *Bulletin 629, U. S. Geol. Survey*, published a map of the Mexia anticline, contouring the shallow gas sand, which he correlated with Nacatoch sand of northern Louisiana.

one mile, and the average width one-half mile. The belt of heavy production extends back from the fault only one-quarter mile.

Both fault and fold trend northeast with the strike of a monocline of Cretaceous and Tertiary beds, which dip gently to the southeast

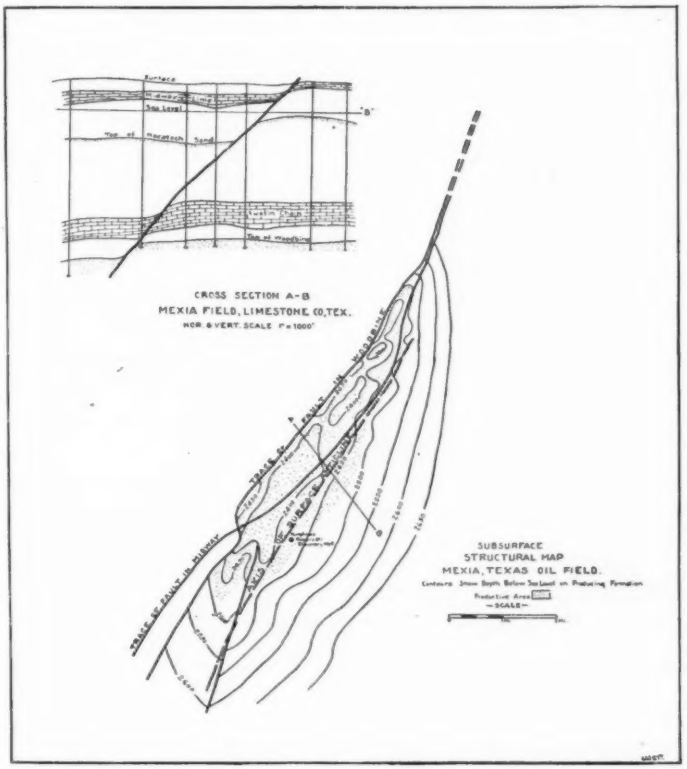


FIG. 1

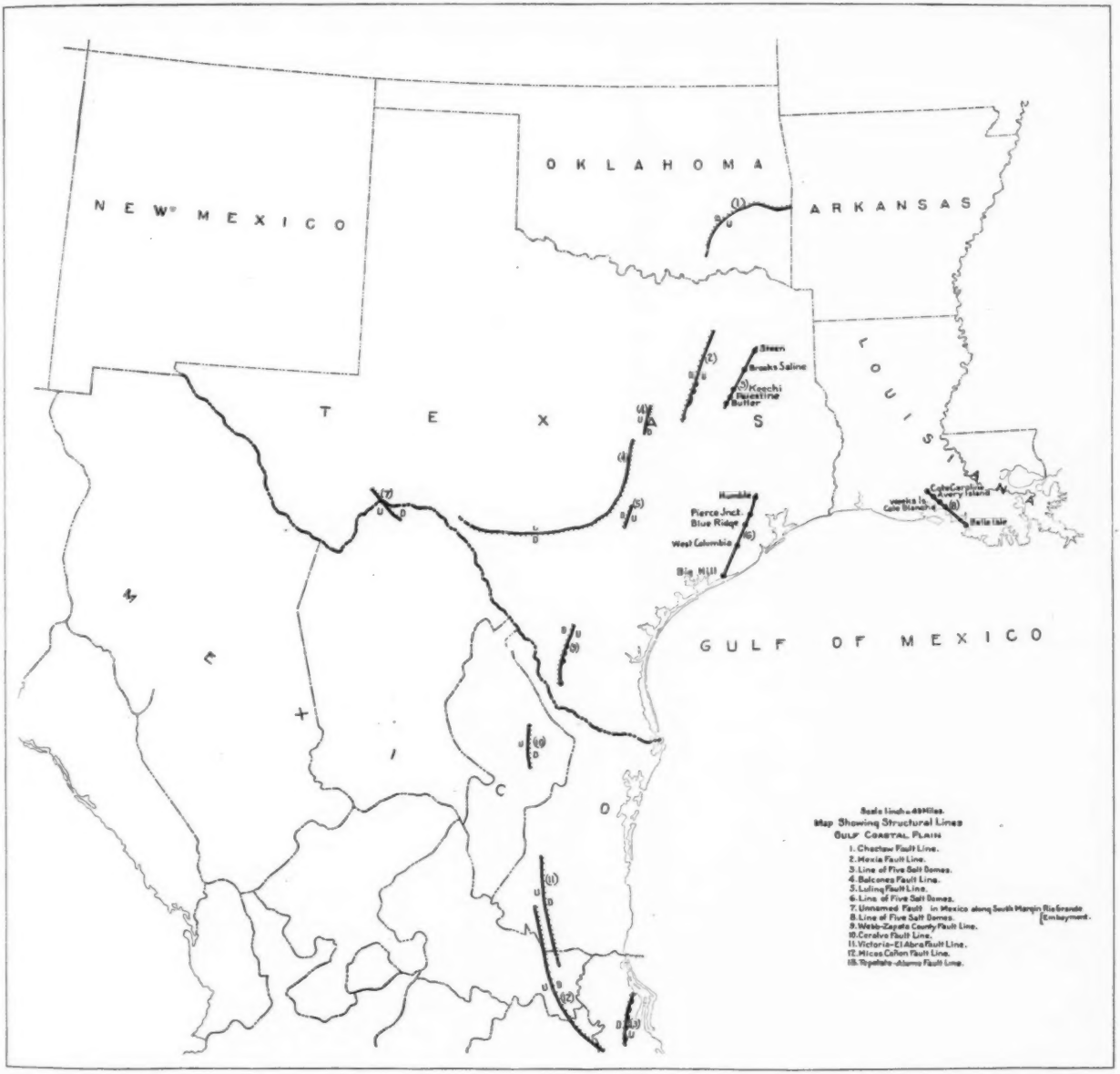
away from a parent land mass of Paleozoic and older rocks in central Texas, into the geosyncline of eastern Texas. The strike of the fault at Mexia changes direction slightly along its course and apparently makes a sharp detour at one point (see Fig. 1). The fault plane dips west at the remarkably flat angle of about 50° along the

middle of the producing area (Sec. A–B, Fig. 1), but steepens toward either end. Toward the south, the throw appears indeed to be reversed since the trace of the intersection of the fault plane with the basal Midway limestone crosses the trace of the intersection with the Woodbine sand near the southern end of production. Another smaller fault which does not appear at the surface, nor affect the production, drops the Woodbine sand to the west along a line east of, and roughly parallel to, the main fault in the southern end of the field. The simple fault system shown in the accompanying figure may in reality be complicated by a number of other minor faults, but the important fault which limits production in the Woodbine sand and the only conspicuous fault in the surface beds are as indicated.

The sand on the upthrow side of the fault is some 250 feet higher than on the downthrow side in the middle of the field, descending gradually along the strike of the fault as the throw decreases toward either end. The oil accumulation is greatest in the highest part of this arch against the flat-dipping central portion of the fault, the plunge toward either end tending to prevent escape by longitudinal movement along the fault.

If the position of the principal known faults around the margin of the Gulf of Mexico be indicated even roughly on a map (Pl. II), the Mexia fault immediately becomes an integral part of a larger fault system. This system is dominated in Texas by the Balcones fault zone which encircles the south and east side of the area of Paleozoic and older rocks in the central part of the state, throwing the younger flanking sediments down on the south and east. The Cretaceous rocks have slipped down along the Balcones a maximum distance of about 1,000 feet, although not all the displacement occurs along a single plane, and along some faults in the zone the beds are even upthrown on the east. The latest movement along the Balcones is clearly comparatively recent; Baker[1] having correlated it with late Pliocene folding in southwest Texas. It is known from the records of deep wells along the Balcones, however, that the buried older rocks have also slipped down to the east, even farther than

[1] C. L. Baker, "Review of the Geology of Texas," *University of Texas Bulletin 44*, Austin, Texas.


NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
TEXAS
Steen
Brooks Saline
Keechi
Palestine
Butler
Humble
Pierce Jnct.
Blue Ridge
West Columbia
Big Hill
Cote Carshin
Avery Island
Weeks Is.
Cote Blanche
Belle Isle
GULF OF MEXICO
Scale 1 inch = 69 Miles.
Map Showing Structural Lines
GULF COASTAL PLAIN
1. Choctaw Fault Line.
2. Mexia Fault Line.
3. Line of Five Salt Domes.
4. Balcones Fault Line.
5. Luling Fault Line.
6. Line of Five Salt Domes.
7. Unnamed Fault in Mexico along South Margin Rio Grande Embayment.
8. Line of Five Salt Domes.
9. Webb-Zapata County Fault Line.
10. Corsicana Fault Line.
11. Victoria-El Abra Fault Line.
12. Micos Cañon Fault Line.
13. Tepetate-Alamo Fault Line.

the Cretaceous has, and, it is inferred, therefore, that the Balcones has been a line of displacement in earlier time; perhaps even back into earliest earth history.

The Choctaw fault in southeastern Oklahoma (see Pl. II), is in close alignment with a possible continuation of the Balcones, but is of pre-Cretaceous age and has its downthrow to the north and west. More clearly related to the Balcones, is the group of faults in Mexico, which, because of their similarity, appear to have resulted from identical stresses farther south along the Gulf Coast. Like the Balcones, these faults, following the margin of the Gulf Coastal Plain, drop the beds east of them; the displacement at places aggregates thousands of feet however, and the faults are correspondingly grander, more profound earth features than the Balcones. Likewise, as in the Balcones fault zone, there are minor reverse displacements in the Mexican fault system which bring the beds up again on the east side of certain breaks.

The Mexia fault has the appearance from its position and trend as shown in Plate II, of a possible en-enchelon extension of the Balcones, the displacement along which decreases to the north until the fault becomes quite obscure in the latitude of Mexia. But the Mexia fault, in its net effect—for the Mexia fault, like the Balcones, is a zone of faulting rather than a single fault—lifts the rocks on its eastern side, whereas along the Balcones, as has been stated, there is a drop to the east. That is to say, if the Mexia fault is in reality an extension of the Balcones, the local stresses which dropped the beds to the east along the Balcones not only die out to the north but have been reversed still farther north, where they actually lift the beds on the east side of the Mexia fault.

Moreover, the Mexia fault, or a zone of similar faults with upthrow on the east, continues to the south-southwest parallel to the Balcones where this fault is itself strongly developed. Obviously in this region the Mexia fault does not replace the Balcones. Furthermore, as has already been intimated, the downthrow is not exclusively to the east along the Balcones nor to the west along the Mexia line. In both these zones as well as in one at least of the faulted areas in Mexico a reaction from comparatively profound downthrows to the east along the western edge of each individual

system is expressed by moderately elevated blocks along the eastern edge of the same system. The diagramatic section across the Mexia zone from Tehuacana to Mexia, which, together with Hill's[1] section across the Balcones along Colorado River is reproduced in Figure 2, shows this relation clearly.

As a matter of fact, briefly stated, both the Mexia line of faulting and the Balcones, as well as the faults in Mexico farther south, are clearly related in their origin to a single general cause, namely, the persistent sinking of a great geosyncline or negative element of the

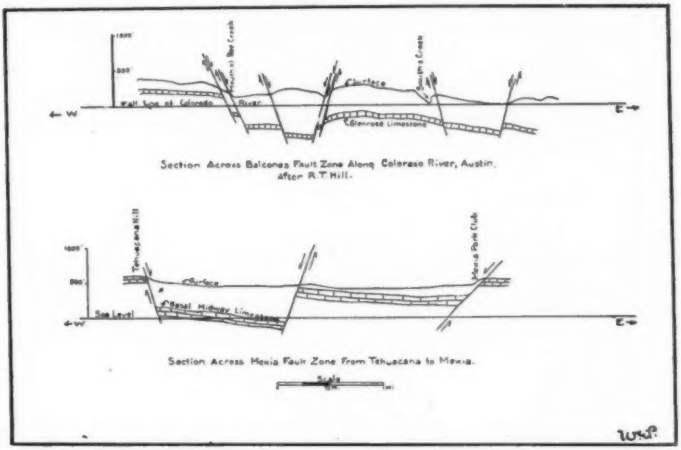

Section Across Balcones Fault Zone Along Colorado River, Austin, after R.T. Hill.
Section Across Mexia Fault Zone From Tehuacana to Mexia.

FIG. 2

earth's crust, the position of which is marked today by the Gulf of Mexico. Intermittently, throughout a large part of geologic time, sediment has been poured into this basin. This load will have tended always to sink and slip away from the margins toward the center of the basin, and marginal faults like the Balcones, with a drop on the basin-ward side, would result from such tendency. But this sinking and downward slipping at the margins of the basin undoubtedly results in consequent buckling and upward reaction farther out in the basin. Concrete evidence of such upward

[1] R. T. Hill, "Geology and Geography of the Black and Grand Prairies," *Twenty-first Annual Report, U. S. Geol. Survey.*

movement is to be seen in the lines (indicated on Plate II), along which plugs of salt, or salt domes have been forced upward from deeply buried salt beds in the central parts of the basin. Due to the same reacting forces, perhaps, the line of faulting on which Mexia is situated, lying out in the basin from the marginal downward slips along the Balcones, raises the beds east of it to an elevation above their normal position. Explained in this manner, the Mexia fault zone must have been formed primarily as a result of nearly east-west compressive stresses, with shear, horizontal movement, and even tension as probable incidental details.

Mexia will probably produce a total of forty-five or fifty million barrels of oil from the Woodbine formation, a volume which makes it important among American fields. This accumulation was trapped along a fault, with only incidental minor arching of the beds and in the absence of any such anticline as generally controls production in beds of equally recent origin elsewhere. The anticline at Mexia would appear insignificant for instance, in Wyoming. Yet faults are rated as of minor importance among recognized factors in the trapping of petroleum. Text books accord them faint praise, to be mentioned along with lensing sands and arrested monoclines as possibly, but rarely, reservoir-forming; or even denounce them as wholly baneful in their effect. But Mexia is not the only example of an important oil field along a fault. It is worth while in this connection to consider the famous Tepetate-Toteco-Alamo line of fields in Vera Cruz, Mexico, the unparalleled accumulation along which is also controlled by faulting. Plate II indicates this Tepetate-Alamo fault in its relation to other faults at the margin of the old basin, and Figure 3 shows diagramatic sections through this field, along with Mexia and the recently discovered pool at Luling, Texas, in their precisely similar general structure.

As a matter of fact, faulting is associated with and probably is the controlling structural feature of all the oil fields in the relatively flat-lying beds of the Gulf Coast Plain, from the Lower Cretaceous up to the Pliocene. A number of fields in north Louisiana produce oil only in the vicinity of faults. Around the Gulf Coast salt domes, concomitant faulting with resulting fractures and squeezing is undoubtedly more important than any doming effect

in building up the remarkable petroleum accumulations which mark those intrusions. The prominent escarpment along which a half-dozen fields in Webb and Zapata counties, Texas, have developed recently is almost surely a fault scarp modified by erosion and the oil accumulation there is unquestionably due to faulting (Pl. II).

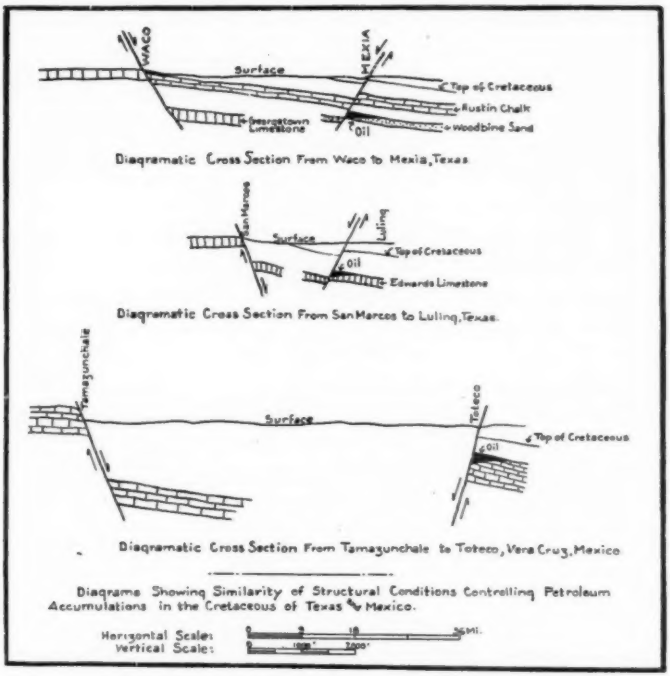


FIG. 3

It has been generally held that, while minute warping may influence the movement of petroleum in old, compacted rocks like the Paleozioc beds of the Mid Continent fields, yet folds of considerable magnitude, such as those which characterize the producing areas in Wyoming are requisite to petroleum deposits in the geologically younger rocks. If this were true then the Gulf Coast Plain not only would promise but little in the way of future production

but could scarcely have yielded any output of commercial importance in the past since both the undeveloped territory, and the old fields in this area are alike devoid of large folds. The flat-lying beds of this region are extensively faulted, however, and from old fields in the vicinity of these faults, nearly a billion barrels of oil have already been produced. The displacement, the fracturing, and particularly the friction which are developed locally through faulting appear to be adequate substitutes for the anticlines which have more commonly been associated with petroleum accumulation. The large undeveloped area in the Gulf Coastal Plain, therefore, continues to be important in its petroleum possibilities in spite of the absence of folding within its boundaries.

OCTOBER 15, 1922

DISCUSSION

F. F. HINTZE: Have you been able to determine the age of the fault at Mexia? And is it your opinion that the oil accumulated at the place where it was recently found after the faulting had taken place?

WALLACE PRATT: Faulting continued along the Balcones escarpment as recently as Pleistocene times. It was probably active also earlier than Cretaceous times. The activity, therefore, was progressive with periods of quiescence. Practically all the movement at Mexia was post-Wilcox and pre-Pleistocene. The oil accumulated in its present position subsequent to the initiation of the fault movement.

F. H. LAHEE: May I add a few remarks in reference to the conditions of faulting at Mexia? There are some geologists who believe that there may be a large thrust fault not far west of the normal fault at Mexia, this thrust fault having a trend probably nearly parallel to the normal fault. Personally, I have not been able to satisfy myself for or against this idea, but the facts may be worth presenting here.

In a strip of country parallel to the Mexia normal fault and just west of it a great many driller's logs have recorded in them either two comparatively thick chalk bodies or one chalk from one to three hundred feet thicker than the normal Austin chalk. It was this which first suggested the possibility of a reverse fault, for a considerable thickening or a repetition of a stratum can be brought about only by reverse faulting, if faulting is the cause.

Now, against this conception is the idea held, I believe, by Mr. Pratt that the upper part of this reported thick chalk represents a stray chalk commonly found in the Taylor above the true Austin chalk, and that the drillers expecting

the Austin chalk at a depth of about 2,100 or 2,200 feet, incorrectly recorded the stray chalk on the downthrown side of the fault as Austin chalk. Mr. Pratt also thinks that this stray chalk may have been locally hardened near the fault so that it more closely resembles Austin chalk than in its normal condition.

While this explanation sounds reasonable enough, we may do well to bear in mind that not only has this apparent duplication of the chalk been noted, but also reasons have been given by certain geologists for believing that wells outside the Mexia field and along the trend of the main Mexia fault, other formations have been greatly thickened or repeated. Statements to this effect have been made of the Eagle Ford, the Woodbine, and the Del Rio Clay. I regret that I cannot affirm or deny any of these from personal observation. I hope that we shall know more about this problem at some future time.

Referring now to Figure 1, observe the relation between the trace of the Mexia fault in the Midway lime and its trace in the Woodbine sand. At the north the traces are nearly coincident, indicating that the fault is here nearly vertical. In the middle part of the field the traces diverge, the fault there assuming a dip of between 40° and 50°. Toward the southern end of the field the traces cross.

The western edge of production essentially coincides with the trace in the Woodbine sand. The relations here shown may be explained in two ways; either there is one fault which is normal north of the point where the fault traces, shown on the map, intersect, and is a reverse fault south of this point, or there are two intersecting faults, one with a 40–50° west dip, and the other with an eastward dip and a strike somewhat more nearly north and south than the westward-dipping fault. In this instance, also, I have not satisfied myself as to the conditions really existing, and I think Mr. Pratt agrees with me that we prefer to present the facts and theories, such as we know them, and hope for subsequent enlightenment.

Before closing let me call one more fact to your attention. Whether there is only one Mexia fault which is normal in places and reverse in other places along its trend, or whether there are two or more sub-parallel faults, including a reverse fault, in close proximity to the western edge of the Mexia field, I cannot readily conceive of the origin of either set of conditions without requiring the operation of compressive thrust forces. I think we shall find that these faults were not the result of simple tensional forces, but rather of torsional forces, including components of both tension and compression, and closely associated with the great regional stresses involved in the settling of the sedimentary prism of the Mississippi embayment.

E. Russell Lloyd: One possible explanation of the apparent duplication of formations in some of the Mexia wells was suggested to me by Mr. Whitehead in a recent conversation. That is, that the exceptional thickness may be due to drag along fault planes.

Frederick G. Clapp: At a time of reaction in favor of the agency of faults in accumulation of oil pools we may wisely avoid swinging hastily to the con-

clusion that faults are an essential element of accumulation in a field which has suitable causes of accumulation aside from the faulting. Thus, the definite, although minor, fold at Mexia will explain the accumulation of oil in the Woodbine sand without the necessity of recourse to a theory of fault agency. The production in the abandoned gas sand overlying the oil field extended several miles beyond the developed oil field along the same axis; the folding in the shallow sand appears to be more definite than in the oil sand, and there appears to be no question that the anticline itself has been the cause of gas accumulation along it. There appears to be no necessity for or consistency in assuming quite a different cause of accumulation in the Woodbine from that in the gas sand. Is it not more probable that, since the fold and the fault are evidently due to a single cause, the accumulation of gas in the shallow sand and of oil in the Woodbine are also due to one cause, viz., the presence of the fold, modified, if you please, by the contiguity of the fault to the west, forming thereby a more perfect catchment than would exist from the anticline alone? If the fault is the cause of the accumulation, why did not some oil rise along it into the gas sand also?

WALLACE PRATT: Mr. Clapp's point is well taken; it would be a mistake to disregard folding completely now that we have some evidence that faulting exerts a control over accumulation. Nevertheless, a majority of the men familiar with conditions at Mexia will agree with the main premise of our paper, that is that faulting controls accumulation there with only subordinate influence from the fold on the upthrow side. The abandoned gas field does not follow the fold beyond the limits of the oil field, as Mr. Clapp suggests, but it does follow the fault beyond the oil field in either direction. And shallow gas in the same sand is found elsewhere in this general locality along similar faults. The fold at Mexia does not extend far beyond the limits of the oil field there but the fault does and with it the shallow gas. We do not assume, as Mr. Clapp infers, a different cause of accumulation in the Woodbine sand and in the shallower gas sand. The faulting exercises the major control in both cases, with the minor fold on the upthrow side at Mexia a contributing factor. It is true also that the shallow gas sand at Mexia as well as at Currie and elsewhere along the Mexia fault system did make oil, although in small quantity. I would explain the preponderance of gas in the upper sand by assuming that the source of the hydrocarbons was below the Woodbine sand, and that most of the oil was trapped in the Woodbine while the gas, more readily fugitive, moved farther along the fault to the upper sand. The fault at Mexia is certainly the main controlling structural feature. There might still have been a considerable field at Mexia in the entire absence of any fold but without the fault there would have been no field except where a very much larger and more vigorous fold were present than the little anticline at Mexia.

F. H. LAHEE: I entirely agree with Mr. Pratt. The accumulation of petroleum in the Woodbine sand at Mexia was unquestionably controlled by the fault which bounds the field on the west.

WALTER STALDER: Although the accumulation of petroleum along faults is a comparatively new subject in the Gulf Coast folds, it has long been recognized as a factor of accumulation in certain California fields. It is my impression that in connection with this subject much profit may be derived scientifically by a study of those California fields where much of the geology is revealed at the surface and considerable work has been already done. Some references to California fields in which faulting is prominent, follow: W. L. Watts, *California State Mining Bureau Bull. 2*, p. 60 (1896), and *Bull. 19*, p. 32, fig. 6, and pp. 185–201 (1900); G. H. Eldridge, and Ralph Arnold, *U. S. G. S. Bulletin 309*, pp. 29–101 and 108–133 (1907); Ralph Arnold, and Robert Anderson, *U. S. G. S. Bull. 322*, pp. 104–106, map and sections C–C and F–F (1907); Paul W. Prutzman, *California State Mining Bureau Bull. 63*, pp. 173–174, 197–204, 217, 248–250, 261, 295 (1913); Clarence W. Waring, *California State Mining Bureau Bull. 69*, pp. 353–360, 366–367, 381, 387, 395 (1914).

JOHN RICH: If, as I understand from Mr. Pratt's discussion, the accumulation of oil at Mexia is controlled by the fault and is due to the faulting and fractional distillation along the fault, I should like to ask why there should not be accumulation also along the west side of the fault and if lack of accumulation on the west side is attributed to westward migration up the dip, I should like to ask why the oil on the east side of the fault did not also migrate up the dip to the crest of the anticline.

WALLACE PRATT: In reply to Mr. Rich's question, I would state first, that accumulation is lacking on the west side of the fault because that is the downthrown side on which no suitable trap is formed. On the downthrown side the broken edges of the beds are dragged upward and upward-moving fluids are free to ascend farther along the fault. On the upthrown side, on the contrary, the edges of the beds are dragged down and fluids entering them under hydrostatic pressure are trapped between the westward drag along the fault and the eastward normal dip immediately to the east of the fault. It is possible, furthermore, that the Eagle Ford shale, a petroliferous shale immediately above the Woodbine sand in its normal position, is the source rock at Mexia. If this were the case, the source rock on the downthrown side of the fault at Mexia would be in juxtaposition with the Woodbine sand on the upthrown side and oil from the source rock would move immediately into the sand along the fault. The Woodbine sand on the downthrown side, however, would be in contact across the fault with barren Lower Cretaceous limestone and would receive no oil unless downward migration from the overlying shale were effective. Whatever the source of the oil, it would penetrate the Woodbine sand on the upthrown side of the fault pushing the water from that sand down dip until equilibrium were established regardless of the position of the crest of the anticline. In reality, however, the crest of the anticline at Mexia is pretty well occupied by oil, although the oil has not moved far down the eastern flank of the fold.

OIL AND GAS IN THE TEXAS PANHANDLE

WALLACE E. PRATT
Humble Oil and Refining Company, Houston, Texas

A half dozen years ago one of the most intelligent geologists in Texas was asked if it were not reasonable to undertake exploration for petroleum in the Texas Panhandle. His reply, based on a broad general knowledge of geological conditions in western Texas, and prefaced with a brief but thoroughly logical and plausible explanatory analysis, was an unqualified negative. The site, throughout most of Paleozoic times of a broad, deep sea in which only relatively pure limestones would be formed, presumably; still marked at the end of the Permian with a desiccating remnant of this sea into which a great thickness of non-organic, thoroughly oxidized terrestial detritus had been swept, and deprived through all this lapse of time of earth stresses which then were held to be essential to the growth of folds in which petroleum could accumulate; such a geologic province, this geologist contended, failed altogether as to petroleum prospects.

Yet, today, near Amarillo, literally in the center of this condemned region, are more than a dozen gas wells, several of which have gauged as much as 100,000,000 cubic feet daily flow, together with five oil wells capable of an aggregate daily production approaching 1,000 barrels. How can this development be reconciled with the reasonable forecast which preceded it? Was the prediction totally ill-founded; or is the showing to date merely a flash in the pan with commercial failure the sure ultimate reward for the wildcatter in west Texas?

In the first place the orginal drilling and the discovery well in the Panhandle resulted from something more than a broad general knowledge of the geology of west Texas such as was possessed by the geologist whom we have quoted. Charles N. Gould, the geologist to whom the discovery of the petroleum deposits of the Panhandle must be credited, based his recommendation upon a detailed

acquaintance with certain features of Panhandle geology gained through months of personal investigation in a governmental survey of underground water supply in that territory. Gould knew that in spite of the absence of all diastrophism in this region, anticlinal folds were present in the vicinity of Amarillo which, whatever their origin, were adequate traps for commercial volumes of petroleum. This fact alone, he argued, justified exploration, and through his influence exploration, which subsequently proved the gas field, finally began.

In some degree, then, the unfavorable analysis of the Panhandle erred in its basis of fact, since suitable geologic structure, which it assumed through deduction to be non-existent, is actually present there. As a matter of fact, we know today that favorable geologic structures are very commonly formed in the absence of tangential earth stresses which the average geologist depended upon five years ago. Moreover, the non-organic red beds which were thought to be very thick and were generally conceded to be incapable of petroleum genesis, proved only a surface mantle at the site of the discovery well, and within easy drilling depth strata of quite different character were encountered. Thus the basis for the opinion quoted in the preceding paragraph fails and that analysis of the Panhandle is accordingly unsound. There is favorable structure in this region and the beds beneath the surface there do contain some petroleum. Does it follow then that the Panhandle is certain to develop great petroleum fields?

The discovery well in the Panhandle was drilled about 30 miles north of Amarillo on top of the John Wray dome. This dome is 15 miles in diameter and has a closure of several hundred feet, as displayed by the attitude of a Permian limestone on the surface of its south and east flanks and by well records on the north and west, where a mantle of late Tertiary sands conceals the Permian rocks. The discovery well made probably 15,000,000 cubic feet of gas and subsequently the whole dome, over an area of some 200 square miles, has been proven for gas, which comes from several horizons between 1,600 and 2,300 feet beneath the surface.

In Carson County, 25 miles east of the discovery well and across the deeply entrenched valley of Canadian River, is another similar

dome, half concealed at the surface by Tertiary sands, on top of which three large gas wells have been drilled. On the flanks of this dome—called the Four Six dome after the ranch on which its crest is exposed—and on a small fold just north of it, are the only oil wells yet obtained in the Panhandle. The Four Six dome is as large as, if not larger than, the John Wray dome.

The Bravo dome—the name in each case was originally used by Gould—larger perhaps than either of these, is situated in Oldham County, 70 miles west of John Wray dome. Several wells have gone down on top of it without success but no well has been drilled on its flanks.

On a small dome on Tuck-Trigg Ranch, 10 miles south of John Wray dome, a single small gas well has been completed.

Finally, some 15 miles east of the center of Four Six dome, on concealed structure which possibly is still a part of Four Six dome, a gas well has just been drilled. Except for several small domes which are situated a short distance north of the Four Six dome, no favorable structures other than those already noted appear at the surface in this region; that such structures exist, however, concealed beneath the surface blanket of Tertiary sands, can hardly be doubted, in spite of the fact that of the large number of wells drilled to date away from the known structures, none has encountered any promising evidence of petroleum. Figure 1 shows these several geologic structures.

The three large structures at Amarillo have cores of crystalline rocks at depths of about 2,000 feet. Sidney Powers[1] has already recorded this fact and has explained the domes in the surface rocks as the result of compacting and subsidence of comparatively soft sediments around the flanks of the "buried hills" which they have engulfed, with consequent arching of the beds across the summits of the "buried hills." The essential correctness of this theory is substantiated by the data at hand, and is generally accepted among geologists familiar with the Amarillo field.

The logs of the wells on these structures are uniform; red beds, sands, and clays for the first 500 feet or so; then another 500 feet

[1] Sidney Powers, "Reflected Buried Hills and Their Importance in Petroleum Geology." *Economic Geology*, XVII (June–July 1922), No. 4, p. 233.

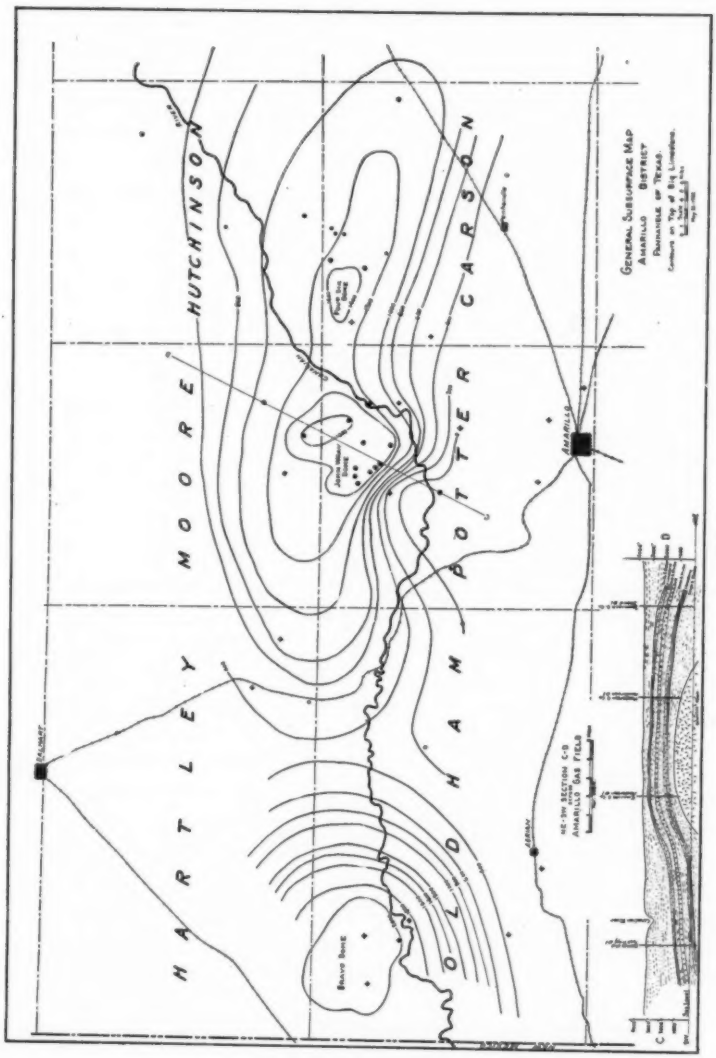

HUTCHINSON
MOORE
POTTER
CARSON
HARTLEY
OLDHAM
AMARILLO
GENERAL SUBSURFACE MAP
AMARILLO DISTRICT
PANHANDLE OF TEXAS
NE-SW SECTION C-D
AMARILLO GAS FIELD

FIG. 1

in which limestone and gypsum are conspicuous; followed by red beds with varying thickness of rock salt, usually in several beds, and aggregating as much as 300 feet in some cases; red beds with thin layers of gypsum, anhydrite, and limestone continue to a depth of from 1,500 to 2,000 feet when the so-called big limestone is encountered. This limestone is some 600 feet in thickness and is the principal gas-producing horizon; beneath it the wells on structure encounter minor thicknesses of red and blue shales, with arkosic sands of sharp quartz and feldspar fragments in which oil or gas occurs until within 200 feet or so below the Big limestone, fresh crystalline rocks are penetrated. A half-dozen wells on the three main domes in the Amarillo region have stopped drilling in fresh, hard, crystalline rock. Several wells on the flanks of the domes have continued through the arkosic crystalline rocks which appear in these cases to be arkose, and have re-entered limestone. In wells drilled entirely off structure the red beds section is much thicker, no arkose is encountered, the zones of rock salt, are often repeated several times, and the limestone series may never be reached even in deep wells; a 4,000–foot hole 30 miles south of John Wray dome, for example, failed to reach the big limestone, or any arkosic or crystalline rocks. The Prairie Oil and Gas Company's Farwell No. 1, 25 miles west of John Wray dome had no crystalline rocks but finally penetrated the limestone series at 3,400 feet, and continued in it without material change in character to a total depth of 5,012 feet. This well obtained no oil or gas.

The limestone which is the principal gas-producing horizon in these fields is dolomitic, crystalline, light gray or brown in color, and often extremely porous, due apparently to selective solution. The magnesium content varies and there are minor intercalations or breaks of anhydrite or even blue clay in the formation. In the Prairie Farwell deep test mentioned above, the lower 500 feet of limestone contained little or no magnesium and was dark gray to black in color; minor breaks of black slate occur in this interval and anhydrite was present in cuttings from the bottom of the well.

The predominant crystalline rock encountered in these wells is granite; a coarsely crystalline, brownish red, quartz-feldspar rock, containing orthoclase, plagioclase, oligoclase, and quartz, with only

subordinate mica or other ferro-magnesian mineral. The cuttings are usually fresh-appearing but the rock is of arkosic character in a number of cases, drilling without difficulty and giving away to limestone again in one case after several hundred feet had been penetrated. On the tops of the large domes, however, hard, crystalline rocks appear to be in original position beneath a mantle of arkose; Humble Oil and Refining Company's Burnett No. 2 on Four Six dome, Carson County, Texas, drilled into granitic rocks for 300 feet and was finally lost because of a crooked hole in extremely hard, fresh appearing granite.

Another type of igneous rock is represented by fragments blown out from some of the gas wells. One such fragment from the Greater Amarillo Oil Company's Masterson No. 1, Moore County, depth 1,930–2,070 feet, on top of the John Wray dome is an altered or possibly weathered porphyry with flow structure; another from the Ranch Creek Oil Company's Masterson No. 1, in Potter County, is similarly porphyritic, but with the texture of a probable intrusive. These specimens contain both orthoclase and oligoclase phenocrysts in a ground mass of devitrified glass in the one case, and of cryptocrystalline feldspar in the other: apatite, biotite, and magnetite occur as accessory minerals. No evidence of metamorphism of the overlying shales and limestones such as would be expected along the contact, if the igneous rocks had been intruded into them has been noted.

The red beds and salt in the upper parts of the wells in this territory are of Double Mountain, late Permian age, and the limestone from which the gas comes is to be correlated, presumably, with the limestone encountered beneath the red beds in the Spur well in Dickens County, and assigned by Udden[1] to the lowest Double Mountain and the upper Clear Fork. The limestone in the lower 500 feet of the Prairie Farwell No. 1 which is crystalline and non-fossiliferous, may be as old as the beds from 3,900 to 4,200 in the Spur well, correlated as Cisco, Upper Pennsylvanian, by Udden. Except for the crystalline rocks, therefore, the beds penetrated so far in the Panhandle are principally, if not entirely, Permian; and the oil and gas comes from Permian beds.

[1] J. A. Udden, "The Deep Boring at Spur," *Univer. of Texas Bull.*, Austin, Texas.

The crystalline rocks beneath these structures are probably of pre-Cambrian age. There is every evidence that they are older than the rocks which overlie them and they are similar in character to the granite of the Wichita Mountains in Oklahoma on the one hand and to the granites of northern New Mexico on the other, both of which rocks are generally classed as pre-Cambrian.

The accompanying map and section (Figs. 2 and 3) show the general structural relations of these fields. The several domes are portrayed as the writer conceives them to be, superimposed on

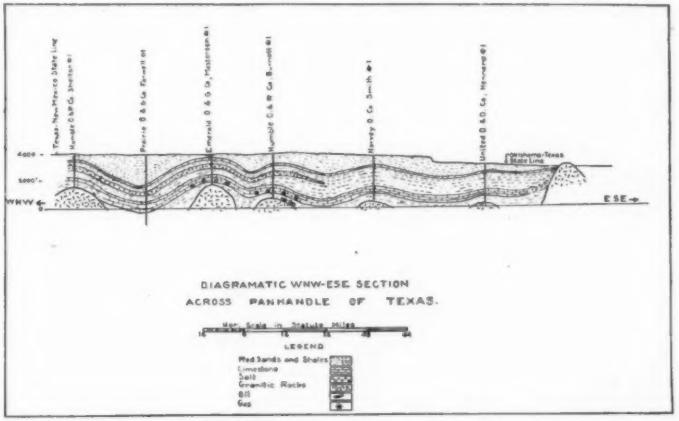


FIG. 2

cores of older crystalline rocks. Such rocks, probably in arkosic form, have been encountered at several places along a line connecting the Panhandle fields with the Wichita Mountains in southwestern Oklahoma, and the occurrence as known at present, makes inevitable the suggested relationship between the crystalline rocks of the two localities. The Panhandle anticlines, then, are arched over the eminences along a buried westward prolongation of the Wichita Mountain range, and although the sketches do not extend far enough west to show it, it is clear that this buried range probably persists westward into New Mexico, where it connects finally with the granites of the Rocky Mountain province.

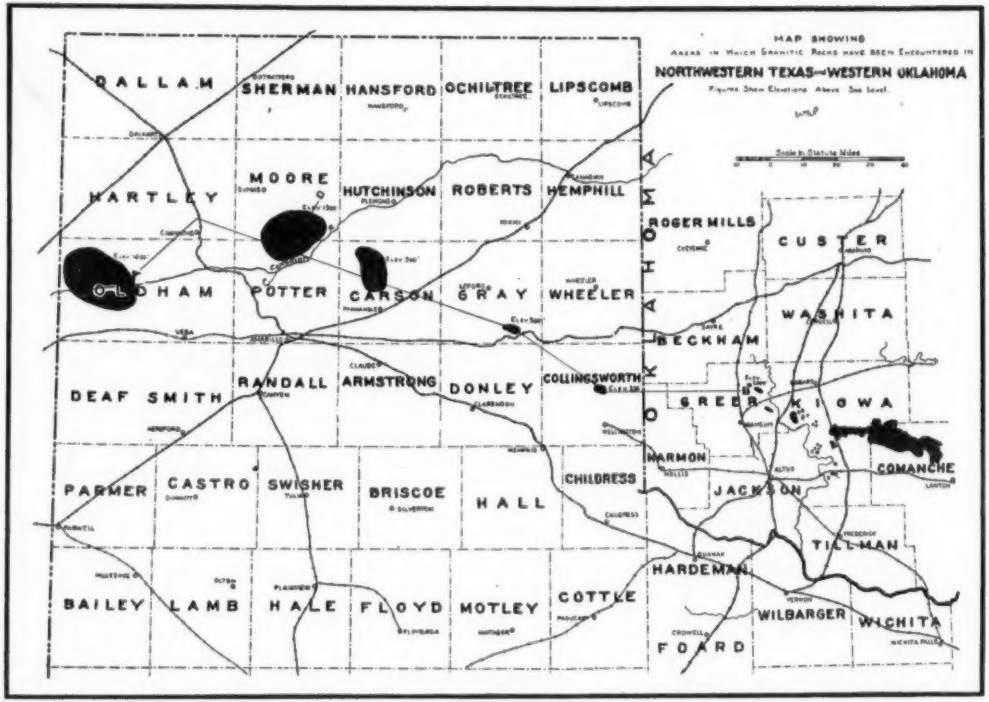

MAP SHOWING
AREAS IN WHICH GRANITIC ROCKS HAVE BEEN ENCOUNTERED IN
NORTHWESTERN TEXAS—WESTERN OKLAHOMA
Figures Show Elevations Above Sea Level.
Scale in Statute Miles
OKLAHOMA
DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
OLDHAM
POTTER
CARSON
GRAY
WHEELER
ROGER MILLS
CUSTER
WASHITA
BECKHAM
DEAF SMITH
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
GREER
KIOWA
HARMON
COMANCHE
PARMER
CASTRO
SWISHER
BRISCOE
HALL
CHILDRESS
JACKSON
TILLMAN
HARDEMAN
BAILEY
LAMB
HALE
FLOYD
MOTLEY
COTTLE
WILBARGER
WICHITA
FOARD

FIG. 3

It is worth while to indicate also the possible structural relation of the Amarillo fields with the Black Hills uplift of South Dakota. Several wells have been drilled along a prominent arch which extends southward from the Black Hills across Nebraska and Kansas toward Amarillo, and on this arch, near Liberal, Kansas, 120 miles north of Amarillo, a large gas well has been completed. In Gove County, Kansas, 160 miles farther north along the same line, a little oil was obtained in a well which encountered Paleozoic rocks relatively high.

As has been said, gas and a little oil occur in the Panhandle in porous parts of big limestone and in arkosic sands overlying the granite cores just beneath the big limestone. The source of these hydrocarbons is believed to be the big limestone itself and the underlying limestone section. Permian limestones are petroliferous as is well known, all over southwestern Texas. Small wells have been obtained in them both in the Toyah region, 500 miles south of the Panhandle fields, and in Mitchell County, 400 miles to the southeast. The Panhandle gas wells, although they produce large volumes, have a uniformly low, closed pressure—regardless of depth or location—of less than 500 pounds per square inch. The gas is sweet, with a characteristic strong odor of ether; analysis shows the presence of unsaturated hydrocarbons in addition to methane, but the gas yields very little gasoline. The oil from wells on the domes is about 37° gravity, and has a fair content of gasoline but contains so much paraffin wax as to congeal at a temperature of about 50° Fahrenheit. The wells so far obtained do not flow, but will pump as much as 200 barrels per day. The wells high structurally make little or no oil, although a fine arkosic sand from one gas well, which sprayed oil temporarily, proved upon analysis to contain 30 per cent by weight of ether-soluble material.

It is worth while, perhaps, in discussing the probable source of the oil, to record the fact that gas and oil from wells very low on structure are of slightly different character than the regular product. Both gas and oil from such wells contain much sulphur and the oil appears to contain more asphalt than the oil from higher on the domes. Such structurally low wells have obtained oil and gas only in the limestone so far, whereas the oil on the domes has

come principally from arkosic sands. The oil from the same limestone series in Mitchell County, where the structure is not pronounced, is likewise asphaltic and contains sulphur.

Most geologists will probably concede but little promise to the petroleum possibilities of a geologic section such as has been described, or to fields which have shown the characters developed to date in the Panhandle of Texas. Limestone is commonly classed as only a meager source of petroleum, and the Panhandle fields, though large, are essentially gas fields with relatively low, closed pressure. Nevertheless, the writer anticipates a fairly large commercial petroleum production in the Panhandle. The reservoirs are so large and the source rocks, even though of poor quality, are present in such abundance as to make probable accumulations of commerical importance. Individual wells will be small under the conditions described and no profit will attend operations in this region of magnificent distances until oil commands considerably more than the present prices.

There is to be borne in mind moreover, the fact that, although no evidence of shales, muds, or organic shallow water deposits of other character has been detected around the buried granite masses already outlined by exploration, yet somewhere along this submerged area, with its former shore line extending eastward to the present Wichita Mountains, shallow estuaries, mud flats, or other conditions conducive to the origination of large volumes of oil may well have existed.

Altogether, then, the geologist who six years ago dismissed the Panhandle as impossible for petroleum, would be obliged today to modify his condemnation in some degree. He could still maintain, however, that his client should think twice before investing there at present.

DISCUSSION

E. B. STILES: Have you observed any evidences of faulting at Amarillo?

WALLACE E. PRATT: The extremely steep dip in the sub-surface beds on the south side of John Wray dome, which is as much as 1,500 feet in 2 miles might very well be interpteted as evidence of faulting. The surface beds, however, do not dip nearly so steeply and do not appear to be faulted. Probably the older formations are faulted at depth along this line of steep dip.

H. W. Bell: I should like to ask Mr. Pratt how he accounts for the low pressure in this area?

WALLACE E. PRATT: I presume the low pressure of the gas in this territory is due to incomplete saturation. The reservoir is so large that the volume of gas available is insufficient to fill it above the water level to a degree where the gas pressure will equal the hydrostatic head. The situation may be controlled in part by the intake for surface waters being at a comparatively low elevation at the outcrop so that the hydrostatic head is lower in reality than the depth of the wells would indicate. In this comparatively arid region, also, the water-saturation of the reservoir beds may be low.

P. B. WHITNEY: The producing gas fields of Wyoming have wells with rock pressures of from 800 pounds to 1,200 pounds per square inch which are in accord with hydrostatic pressure for the proper depths. The flow of gas varies from 20 to 60 million cubic feet daily.

The Amarillo district has gas wells of pressures, say 435 pounds per square inch, regardless of depth and not in line with the anticipated hydrostatic pressures. The gas flow, however, is 100,000,000 feet. With large rock pressure should we not expect large flows of gas, or the greater the pressure the greater the flow? In comparison of Wyoming and Amarillo wells, the converse is true. Do you attribute the tremendous flow with so small a rock pressure to variation in porosity of reservoir or what is the controlling factor?

WALLACE E. PRATT: The closed pressure on a gas well is not the sole factor which determines the volume of flow. Even where two wells are completed with the same size casing, one with comparatively low pressure may make a larger volume of gas daily than another with a much higher gas pressure. The explanation lies in part in the character of the reservoir. Some gas sands are so tight or non-porous that in spite of high pressure only a small volume of gas can flow through them to wells. The Amarillo reservoir rock on the other hand is very open, perhaps even cavernous in places and gas flows readily through it.

L. C. SNYDER: In connection with the thick limestone series in the wells in the Amarillo district it is interesting to note the great thickness of lime and limey shale in wells in Hall County and in southwestern Collingsworth County, at the eastern edge of the Texas Panhandle. Three wells in this region encountered nothing but limestone and calcareous shale, after passing through the red beds, although drilled to nearly 4,000 feet.

The gas well near Liberal, Kansas, although considerably distant from the Amarillo gas field, may be indicative of similar conditions to the north. The presence of gas and oil near Sayre, Oklahoma, should also be noted.

If the age of the limestone and calcareous shale in the Hall and Collingsworth wells is the same as that in the Amarillo gas field, I believe the possibility

of part of it being Cambro-Ordovician (Arbuckle) age should be considered on account of the proximity of the eastern wells to the Wichita Mountains.

WALLACE E. PRATT: I doubt that any of the sedimentary rocks penetrated at Amarillo to date are as old as Ordovician. The cuttings from the deepest wells show limestones that are fossiliferous and otherwise different from the Ordovician limestone of Southern Oklahoma and Northern Texas. The deep well in Hall County also penetrated fossiliferous limestone, unlike the Ordovician, in its lower part.

H. W. C. PROMMELL: About a month ago I had occasion to map in detail the northern part of the 6666 anticline mentioned by Mr. Pratt. The work covered an area extending from the Gulf No. 1 well on the Burkburnett ranch northward to the south bank of Canadian River.

I found that a number of minor folds were developed on the flank of the 6666 anticline. These minor folds trend in a northwest-southeast direction. Considerable trouble was experienced in mapping the structural attitude of the Alibates limestone on account of the slump and the many sink holes present. The sink holes are in places 2,000 feet in diameter. In order to gain a clear idea of this structure, all depressions and elevations as they now appear in the field were contoured on the regional map. After all the data had been assembled on this map, a distinction between sink holes and actual structural conditions due to folding could at once be made.

Of the wells drilled, the Gulf No. 1 Burkburnett is situated near the apex of the main 6666 anticline. The Silk-Bullington well and the Gulf No. 2 Burkburnett well are located fairly close to the axis of one of the minor structures as mapped by Gould some time ago. The Texas well, which is now drilling, is located on the flank of the main 6666 anticline. While we did not detail the area in the close vicinity of the McGee well, it seems to be located on a more or less north-south line of folding developed on the flank of the 6666 anticline. The Gulf-Dial well No. 1, which is situated on the north side of the Canadian River, seems to be located on a separate structure as the beds rise again toward the north from the north bank of Canadian River.

CHARLES N. GOULD: So far as our observation goes, there is only one surface fault in the Amarillo region. This fault which has a throw of about 80 feet is located south of Canadian River near the mouth of Trujillo Creek, western Oldham County, on the southern part of the Bravo dome. I agree with Mr. Pratt that there is probably a buried fault along the south side of John Wray dome, its location being indicated by the abnormally steep dips at this place.

Both the John Wray dome and the 6666 dome show scores, if not hundreds, of minor folds or blisters on their surfaces. So numerous are these secondary structures (if indeed they be structures) that only the larger of them were taken into account when we mapped the domes.

Masterson No. 3 of the Amarillo Oil Company, located near the (observed) apex of the John Wray dome was thought to be a granite well, and was stopped at 2,195 feet. It then produced over 15,000,000 cubic feet of gas. After being shut in for about two years, drilling was resumed and after penetrating the supposed granite, the drill passed through more than 300 feet of dark blue clay carrying something like 15,000,000 cubic feet of gas additional. At 2,753 feet the well caught fire and destroyed the rig. This is the deepest well on John Wray dome. In view of the fact that the oil found in the Gulf, Silk, Texas, and McGee wells on the 6666 dome and the Dial well on the Plemons dome, occurs at about 3,000 feet, it would appear reasonable to believe that oil may occur at about the same depth on the John Wray dome.

WALLACE E. PRATT: It is true as Dr. Gould states and as is recorded in the body of my paper that several wells have drilled through the granitic rocks into sedimentaries. I am informed also that one well on the John Wray dome drilled through the felsitic rock, noted in the paper as a probable dike or flow, and went again into sedimentary rocks below. It is possible, of course, that the dike rocks are intrusive into the surrounding beds as well as into the granitic rocks. It is true also that the granitic arkose beneath these domes has been explained as part of a sheet of arkose which is widely observed in the red beds series farther west in New Mexico. The difficulty is that the granitic rocks in the Amarillo wells are found, not in the red beds but beneath several hundred feet of limestone, and that they are not found uniformly over the country away from the structural domes. These considerations have led the writer to conclude that older granite in place probably occurs somewhere in each of these structural highs.

CORE DRILLING WITH ROTARY TOOLS IN CALIFORNIA

J. E. ELLIOTT
Los Angeles, California

HISTORY

The first use of the core drill in California for oil prospecting seems to have been made during 1919, when the writer, then in the employ of the Shell Company of California, attempted to ascertain the subsurface structure of an area near Downey and Santa Fé Springs, southern California. Later the Shell Company began experimental coring with a specially designed double barrel core drill for use with heavy rotary equipment, in proved territory in the Coalinga field, for the purpose of locating markers, etc.[1] In 1921 the same company used the core drill advantageously in locating oil sands in the Discovery Well at Signal Hill, Long Beach California.

The continued improvements of the oil field rotary drilling outfit have led to its increased use for drilling wells in California, until at the present time nearly all wells are drilled by this method. The serious drawback to the rotary drill is the difficulty of obtaining accurate formation samples. This factor has been the cause of many failures, particularly in those oil fields where "town lot" drilling for instance, demanded haste. Inasmuch as the rotary method of drilling is the logical one for unconsolidated strata, it became imperative that some means be designed for determining the nature of the formations penetrated.

About the middle of 1921, R. E. Collom[2] called the attention of California operators to the endeavors made in the Mid-Continent fields to overcome this weakness of the rotary system of drilling by the use of a core drill. Late in 1921 California operators

[1] *Summary of Operations, California Oil Fields*, Vol. VI, No. 12, p. 16.

[2] "Notes on Core Drilling Methods in Oil Fields," *ibid.*, p. 3.

became converted to the advantages of core drilling with rotary outfits, and in the short space of one year core drilling in rotary drilled holes has risen from a theory to an established practice.

TYPES OF DRILLS IN USE

Two general types of core drills are used in connection with rotary drilling. These are the so-called single barrel and double barrel core drills. The former is a non-reaming type, while the latter usually reams out the hole to a greater or lesser degree. Various types of scrapers and samplers which take cuttings from the walls or from the bottom of a hole should not be classed as core drills, and descriptions of these are not included in this discussion.

SINGLE BARREL CORE DRILLS

The single barrel, or non-reaming type of core drill, has been described by Scott.[1] This type of barrel has been used extensively in obtaining formation samples from wells in California.

In its simplest form it consists of a length of drill pipe from 3 to 8 inches in diameter with from four to sixteen teeth cut in one end with a hack-saw or oxyacetylene flame. Alternate teeth are sometimes bent slightly in either direction, as are the teeth of a saw to provide needed clearance between the barrel and the core and between the barrel and the walls of the hole. This contrivance is rotated slowly to the bottom of the hole, and when it is decided that enough core has been cut, considerable weight is given to the pipe for the purpose of bending the teeth in to form a basket, and the pipe is withdrawn from the hole.[2]

The advantages of this type of core barrel lie in its low initial cost and ease of manufacture. Offsetting its advantages, are the objectionable features of usually a short length of core; washing and contamination of the core by the circulating mud flush; unreliability of cores due to obtaining compressed mud, cavings, etc.; danger of injury of core due to heat which is not only dependent upon the skill of the operator but also upon the formation penetrated; loss of

[1] W. W. Scott, in "Personal Communication to A. W. Ambrose," *Bureau of Mines Bulletin 195*, 1921, pp. 22–24.

[2] J. E. Elliott and F. C. Merritt, "Core Drilling in California Wells," San Francisco Meeting Am. Inst. Min. Eng., July 11, 1922.

cores due to failure of closing of core barrel which is particularly likely in sand formations; danger of pulling "wet" jobs due to plugging of circulation holes in core drill, which is apt to cause serious danger of caving in the walls of the hole; liability of sticking or freezing core barrel, causing a more or less serious fishing job. Several operators have abandoned the use of the single barrel drill on this last count alone. The disadvantages of this core drill offset to a marked degree, the advantage of the low initial cost of the drill, for the ultimate cost per core is greater than with a double barrel core drill properly operated.

The Okell Core Drill is a single barrel, non-reaming shot drill. It consists of a piece of pipe of any desired length and diameter, on the bottom of which one V shaped cut is made. While coring, special steel shot are poured into the circulation system. This type of core drill is particularly advantageous in consolidated formations, but has little value in the soft, unconsolidated strata prevalent in most California oil fields. It is seldom used in oil field practice to obtain formation samples in connection with heavy rotary drilling equipment. However, operators have made ingenious use of the Okell barrel in fishing. In a few cases where a bit or other relatively small piece of iron has been lost in the hole which could not be fished out, dislodged or sidetracked, cement has been placed in the hole over and around the lost piece of iron. After the cement has set, the Okell core barrel has been run into the hole on the bottom of the drill pipe, and a core, the size of the hole, taken from the cement block. If the work is successful the iron is brought to the surface in the cement core.

Another core or sample-"taker" that comes under the single barrel type, is one known locally as the "punch" or "spudding" core drill. This consists of a short piece of pipe, seldom over 18 inches in length, with a diameter of from 2 to 3 inches. The interior of this core drill is serrated to act as a means of holding the core. The short piece of pipe is screwed into a head, which in turn, is screwed into the drill collar. It is lowered to the bottom of the hole and circulation started and maintained until the bottom is believed to be clean. The pipe is then dropped or spudded into the formation far enough to fill the small punch core drill at the

bottom with the formation. This type of core drill is somewhat more expensive than the basket type described above, but it can be used over and over again. Its disadvantage lies mainly in the shortness of the core and the large number of misses recorded against it. Furthermore unless the hole is absolutely clean the core will consist of compressed mud cavings and scrapings which naturally collect at the bottom, and unless the operator is experienced in coring the results obtained from this type of core barrel are not only inaccurate, but may be misleading.

DOUBLE BARREL CORE DRILLS

There are several types of double barrel core drills in use. The general features of these are similar, but each varies considerably in details of construction. In general, the double barrel core drill consists of two concentric barrels, between which the mud flush passes directly to the bottom of the hole. These two barrels are attached to various types of cutting shoes. The inner barrel, through which the core passes up and is retained, is usually from one to three inches in diameter. This inner barrel may be of any desired length and is usually fitted at the top with a valve which permits the escape of the entrapped fluid. The Union Oil Company and Standard Oil Company of California have developed core drills very similar in construction which drill to full gauge during coring operations. One of the interesting features of the core drill designed by the Union Oil Company is that the inner barrel is designed to remain stationary, while the cutting surfaces and outer barrel rotate. The Interstate Oil Company has designed and is using a core drill which uses cone cutters similar to the cutters of the Reed or Hughes bits, instead of the usual teeth.

The oil field type of diamond drill[1] may properly be included under the heading of double barrel drills, but so far as the writer knows, this drill has not been used in southern California.

The Elliott Double Barrel Core Drill is similar in general design to other double barrel core drills, and will be described in detail as being more or less typical of the type of drill most popular in south-

[1] Frank A. Edson, "Diamond Drilling for Production," *Bull. Am. Assn. Petroleum Geol.*, Vol. VI, No. 2, pp. 91–97. Also, Robert Davis Longyear, "Diamond Drilling in Exploration," *ibid.*, pp. 98–109.

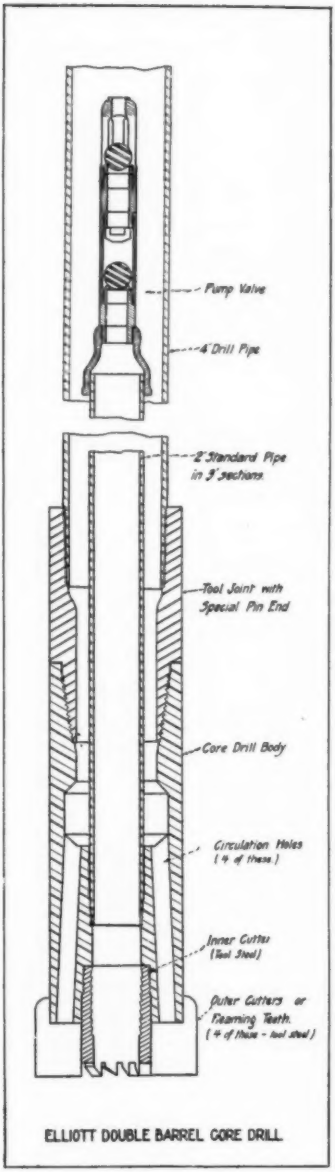

Pump Valve
4" Drill Pipe
2" Standard Pipe in 3' sections
Tool Joint with Special Pin End
Core Drill Body
Circulation Holes (4 of these)
Inner Cutter (Tool Steel)
Outer Cutters or Reaming Teeth. (4 of these - tool steel)
ELLIOTT DOUBLE BARREL CORE DRILL

FIG. 1

ern California at the present time. Naturally this particular drill varies considerably in detail from others of the same general type. The assembled barrel is shown in Figure 1. It is so designed that a core 2 inches in diameter is extracted from a hole drilled $7\frac{3}{4}$ inches in diameter. The outer reamer cutters and inner cutters are especially arranged and designed to obtain the best cutting surface. Wherever possible standard parts, such as the tool joint connections, are used.

ADVANTAGE OF DOUBLE BARREL CORE DRILLS

A properly constructed double barrel core drill is more expensive to manufacture and operate than the ordinary single barrel or basket type of core drill. However, with a double barrel core drill well designed and properly operated, the results obtained by the former more than justify the additional expense. One of the most important advantages of the double barrel core drill over the single barrel drill is that a greater length of core may be obtained with each run. In the writer's operations, many cores are being taken in lengths up to ten feet, although the average length of extracted core, under all sorts of conditions, has been

approximately five feet. This factor is of extreme importance where continuous coring is desired. It is more or less common practice, where the single barrel is used by operators, to extract a short core or sample at more or less definite intervals, usually varying from 5 to 10 feet. Where the underground conditions of a field have been fairly well worked out this procedure is probably satisfactory. However, in areas where little, or nothing, is known of the underground conditions, such a system is not adequate, and progressive operators are insisting upon continuous coring in order that a complete vertical section of the formation at critical depths be obtained.

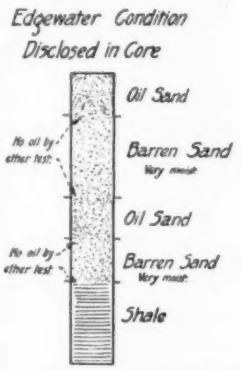


FIG. 2.—Alternating lenses of oil sand and sand suspected of carrying water.

Noteworthy instances of the advantage of continuous coring may be mentioned here. One company in the Santa Fé Springs oil field cored continuously through 300 feet and proved to their satisfaction that the second oil zone contained so little oil that it did not justify the landing of a string of casing and testing out, although this zone is productive a few hundred feet to the west of this particular well. Continued coring located the top of the so-called "Third Zone" in this area, and at the present time this well is producing over 7,000 barrels of oil per day. In another case one of the larger companies attempted to prove by continuous coring, the presence or absence of intermediate water between the second and third oil zones near the top of the Santa Fé Springs structure. Toward the bottom of the second oil zone several cores showed the presence of barren sands interbedded with shales, between oil sands. In one particular instance a core $3\frac{1}{2}$ feet in length, showed that the upper 6 inches of sand carried oil and the next 12 inches of sand was barren of oil even to the extent that the ether tests failed to reveal a trace of oil. Moreover, as the sand was moist and did not seem to carry mud fluid the indications were that the sand carried water. Immediately below this streak of sand were 6 inches of sand carrying oil, followed by another sand of similar thickness apparently carrying water. The lower 12 inches of the core was shale. (See Fig. 2.) Thus

it is seen that intermittent coring is not satisfactory under many conditions.

Cores may be obtained from hard formations and soft unconsolidated sands with the double barrel core drill that cannot be obtained with the single barrel drill. A properly constructed double barrel core drill will penetrate practically any formation that can be drilled by a fish-tail bit. In fact, the writer has taken cores of serpentine and very hard sands, shells, and cherts, as well as of sands so loosely consolidated that they could not be picked up in the hands after having been pushed from the core barrel on to trays.

There is no contamination of the core by the circulating mud fluid with the double barrel type of core drill. The importance of obtaining a clean and uncontaminated core was practically demonstrated on one job in southern California. A short core had been obtained with the basket type of core drill. An "ether cut" of the sand indicated the presence of oil. Inasmuch as the mud fluid used in this well carried a large amount of oil which had been used in the well during a fishing job to free a string of drill pipe, the question arose as to the authenticity of the information obtained by an examination of the sample. To check the results another core of the sand under identical conditions was taken with a double barrel core drill. A thin mud coating, showing considerable oil, surrounded the core. When this mud coating had been scraped away, ether tests of the core proper made even on the outside edges of the cored formation gave not the slightest reaction.

The loss of cores with a properly operated and properly constructed double barrel core drill is less frequent than with the single barrel, or basket, type of core drill. As nearly as the writer has been able to obtain the facts, the probable percentage of extracted cores does not exceed one core for every two attempts made by the single barrel. On the other hand, actual records of the double barrel core drill show that about 95 per cent of the runs are successful. Of the 5 per cent of failures, about half are due to causes not under the control of the operator, such as iron in the hole, extremely hard formations, breakdowns of the surface equipment, etc.

With the double barrel type drill perfect sections of the formation cored through are usually extracted. In a number of cases reliable dips have been obtained from the cores. For example, a dip determined from a core was used to re-estimate the distance to the oil measures in one outlying well. The calculated depth checked the actual depth of the oil sand within 3 feet, the total difference in elevation of the oil sand being about 150 feet.

The heat usually generated by the single, or basket, type of core drill is eliminated by the double core barrel when properly operated. The effect of heat, even though not visible to the eye, is readily detected by a characteristic odor. The elimination of heating is very important in drilling through oil sands as cores are known where heat has been sufficient to dissipate the oil that had been present in the core. In one such case an offsetting well on the same contour employed a double barrel core drill which disclosed the presence of oil 60 feet higher than in the well using the single barrel type.

There is a difference of opinion in regard to double barrel core drills that drill a hole to full gauge as against those that drill a "pilot" hole ahead of the full-sized hole. In the opinion of the writer, the drills which drill a "pilot" hole are most advantageous. A small hole can be drilled and cored ahead a distance of 50 or 60 feet for prospecting purposes before reaming is necessary. The hole can then be reamed to any desired point and a shoulder left on which to land the casing. It might be mentioned also, that the pilot hole method of prospecting is rapidly gaining in favor with California operators.

OPERATION

The proper manipulation of any core drill is extremely important. Even a properly constructed double barrel core drill requires long experience on the part of the operator to obtain satisfactory cores. The occasional coring experience of the average driller is insufficient to insure satisfactory results. This probably accounts for the fact that in many cases cores obtained by use of the double barrel core drill are little better than those obtained by the single, or basket, type of drill, which in turn accounts for the preference of some operators for the latter type. The main reason that the

ordinary driller usually cannot take cores satisfactorily is that his whole training has been toward making speed in drilling. Coring, on the other hand, requires slow drilling with only a small amount of weight on the drill pipe. The work requires care, patience, and a certain amount of imagination.

The proper development of the coring business called for special equipment and special service. This equipment in its entirety comprises specially constructed service cars (Fig. 3), fully equipped with core drills and every accessory required in a coring operation. These include various size subs, tong bushings and core pushers,

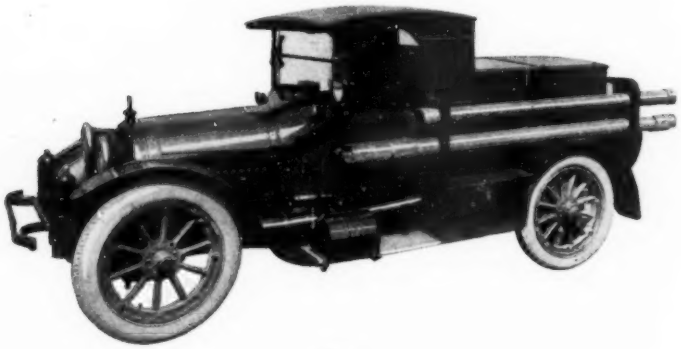


FIG. 3

core containers, labeling tags, ether, test tubes, and other necessary equipment. Each service car outfit is attended by a trained driller who usually has had some engineering experience. The driller in charge of the service car, when called upon to core, delivers the assembled barrel at the well. The regular well crew runs the barrel into the hole on the drill pipe. When the barrel is about one joint "off bottom" the core drill attendant takes charge and does the actual coring, upon the completion of which the regular well crew pulls the drill pipe and barrel out of the hole. When the core barrel has been withdrawn the core driller again assumes charge of dissembling the core barrel and extracting the core. This work requires considerable care.

Every precaution is taken against possible contamination of the core from outside sources. The core is pushed out of the inner core drill into clean containers which are properly labeled, and these are turned over to the representative of the company for which the core was taken. Obviously it is essential to protect a core from contamination by oil from outside sources. Regular well crews are often careless and allow the core to become contaminated with oil. This may happen in various ways, such as by using an oily push rod for extracting the core from the core barrel, handling the core with oil-saturated gloves, allowing the core itself to fall upon the oil-saturated floor, etc. Such contamination, if not known to those in responsible charge of the well, may cause erroneous conclusions and be extremely expensive to the operator.

USES OF CORE DRILLS

The earliest coring in California was for the primary purpose of locating the proper formation for cementing the water string of casing. During the past few months the more progressive operators have taken cores to a greater extent for determining the formations, both prior to and after cementing the water string. In this way the hazard of cementing prematurely, and thus reducing the size of the hole and using an extra string of casing, is lessened. An example of this kind, is furnished by Hamilton 4, in the Santa Fé Springs field, which is located well down on the south flank of the structure. It was necessary to determine whether or not the second zone, or Bell sand, was productive at this point. Without the use of the core drill, the only procedure open to the operator would have been the cementing of a string of casing at the shale layer above this zone as estimated by subsurface correlation of well logs, and to have made a production test. By coring in this well it was determined that the Bell sands at this point did not contain oil. Accordingly, the well was carried on deeper until the third oil zone, known as the Myers, was located at a depth of about 4,650 feet. This well was drilled some distance into the oil zone with the core drill before cementing the casing in order to determine whether or not there was sufficient thickness of oil sands to justify cementing above the first showing of oil encountered. It is interest-

ing to note that this is probably the deepest well that has been drilled to date with 6-inch drill pipe. A 13-inch hole was carried to approximately 4,700 feet, and the 8¼-inch casing was cemented at 4,650 feet. This well is now flowing through the 8¼-inch casing at the rate of about 2,000 barrels per day.

The core barrel has been of material aid in increasing the number of successful cementing jobs. The records of wells which the writer has cored show that less than 5 per cent of the water shut-offs have been unsuccessful. One large company at Huntington Beach has a record of 12 successful shut-offs out of 13 attempts. A well-known drilling contractor has made 14 consecutive shut-offs without a failure and attributes the unusual number of successful water shut-offs to the core drill.

The core barrel has also been found useful in determining the cause of an unsuccessul attempt to cement the water string. By coring it usually is possible to determine whether or not the water entering the well is due to the presence of lower water sand or to a leak around the casing. In one well on which the water shut-off test showed water entering the hole, a core was taken and an oil sand located just below the shoe. This proved that the water was coming from behind the water string. The well was subsequently re-cemented successfully and the well became a good producer of clean oil, thus checking the information obtained by coring.

In the past, cable tools have been in favor with operators for wildcat drilling. This was primarily due to the fact that the log obtained by the use of cable tools was more complete and could be kept in greater detail with less chance of passing up a productive oil sand than where the rotary was used. However, in California sentiment at the present time, is much in favor of the rotary drill, aided by the core drill. Probably 75 per cent of the wildcat wells now being drilled in southern California, are being drilled by rotary tools. It is the writer's opinion that where intelligent use is made of the core drill, more satisfactory results will be obtained in wildcat wells than are possible where even cable tools are used.

An additional advantage of the use of the core drill in wildcat drilling is the possibility of saving one or more strings of casing in case the well is not productive, as thorough coring obviates the

necessity of testing out. This feature has a further advantage of avoiding frequent reductions in the size of the hole.

Of local interest in California are the present plans to drill additional wells on the Dominguez Hill structure which has already been partly condemned by several dry holes. The perfection of the core drill has undoubtedly influenced a decision to re-prospect this structure. Many instances may be cited of the use of the core drill in extending the fields of southern California, in developing the maximum thickness of oil sand, in determining the best horizon in which to land casing, and in solving water problems. In Santa Fé Springs the upper, or Foix sand, was passed through and ignored in the earliest wells. Later this sand was tested out with discouraging results, and the Foix zone condemned by the operators. Continuous coring in a recent well permitted development of the maximum thickness of the zone and the well is at present producing 2,700 barrels of clean oil. The second, or Bell zone, was the first productive zone discovered in this field. The early wells penetrated this zone a distance of 30 to 50 feet before cementing the water string. This zone consists of closely alternating beds of shale and oil sand and the oil is of high gravity, making only a small showing on the ditch. Double barrel coring in later wells proved conclusively that the accepted point of shut-off was too low.

Edge water in the Santa Fé Springs oil field has been very definitely outlined by continuous coring with double barrel drills in various wells. This procedure has resulted in considerable saving in time and money to the operators employing it and they have continued their wells to the third, or Myers sand.

The core drill has also proved of considerable value to operators in the Long Beach field. By use of the core drill the Shell Company first discovered the oil sand in this field. Subsequently the core drill has been relied on for prospecting deeper sands as well as the outlying parts of the field. In one well a core disclosed an interesting edge water condition. A five-foot core of sand was extracted, the upper three and one-half feet of which were saturated with heavy oil, while the lower one and one-half feet were apparently barren of oil. There was no shale parting between the two, but the plane separating them was sharp. The barren sand gave no

test for oil with ether. The southeast limit of this field has been definitely outlined by means of the core drill.

Huntington Beach is another important field in southern California in which the core drill has been successfully used. Operators early learned to depend on the core drill and to its credit belongs the discovery of the northwest extension of this field.

In addition to the immediate use in solving field problems by means of coring, the samples extracted by core drills are being subjected to careful examination and analysis with a view to better correlation of strata. Heretofore this sort of work has been carried on under the handicap of doubtful authenticity of the samples studied, but the core drill furnishes samples of suitable size from definitely known horizons. Various companies in California are taking advantage of this fact to make microscopical examinations of the material extracted and to make chemical analyses of sands and included water.

The rapid growth in the use of the core drill indicates the favor in which it is held by operators of southern California. It is safe to say that operators will never abandon its use so long as rotary drilling is the current practice. The core drill has proved its ability to reduce the overall cost of producing oil, and it is believed that such a test proves its practicability.

NOTES ON THE KEVIN-SUNBURST OIL FIELD MONTANA[1]

FRANK R. CLARK
Sistersville, West Virginia

INTRODUCTION

The Kevin-Sunburst dome is a low dip fold of unusual size. The known closure is about 700 feet and the area within the lowest known closed contour is approximately 700 square miles. The average dip is about 50 to 75 feet per mile and the maximum dip does not exceed 100 feet per mile. The subsurface folding of the oil-bearing rocks conforms closely to the surface folding in the areas covered by present development and it is believed that future drilling will show no marked variations between the surface and subsurface folding.

The discovery well in the field found production at the top of the Madison limestone (Lower Mississippian) or at the disconformable contact between the Ellis (Upper Jurassic) and the Madison. The second producing well found oil in the basal sand of the Kootenai (Lower Cretaceous) about 225 to 260 feet stratigraphically higher than the oil in the discovery well. These are the only two commercial oil-bearing horizons yet found in the field, but small flows of gas have been found in sands of the lower part of the Colorado shale.

FIELD WORK

The writer spent a total of about two months in the field; two weeks in reconnaissance scouting and the remainder in detailed mapping. Plane table and telescopic alidade were used to establish an accurate vertical and horizontal control by primary triangulation. The vertical control was carried on the United States Geological survey datum, and triangulation elevations were checked

[1] Published by permission of Western Petroleum Exploration, Inc., Sistersville, West Virginia.

at several places against "Y" level bench marks with an average error of two feet and a maximum of five feet.

Acknowledgment is here made of the co-operation of the oil operators in supplying well log data and other information which facilitates the interpretation of sub-surface conditions.

PREVIOUS WORK

In 1916, Eugene Stebinger[1] briefly described the Sweetgrass arch, saying in part:

> The arch extends southward from the Sweetgrass Hills to the region beyond Teton River, where it flattens out because of the presence of gentle northward dips induced by the uplift of the Belt Mountains, still farther south. . . . . Most of the arch in northern Montana has not been examined geologically. The possibility of the occurrence of minor folds within the area of the broader arch must be considered, and if any such are present they are important in relation to the occurrence of oil and gas, offering the possibility of getting oil from the Colorado shale at comparatively shallow depths.

Gordon Campbell made a study of this region about 1920, leased a large acreage and drilled the discovery well, but so far as known to the writer, he published no geologic maps or reports.

James F. Kemp and Paul Billingsly,[2] late in 1921 discussed the geology of the Sweetgrass Hills, describing the igneous and sedimentary rocks of the hills and adjacent territory but making no mention of the oil and gas possibilities of the Sweetgrass arch. It contains a detailed section of the sediments from the top of the Madison limestone to the base of the Two Medicine formation.

Early in September, 1922, Arthur J. Collier, of the United States Geological Survey, published a press notice and contour map showing the results of his studies of the Kevin-Sunburst oil field. The text gives a concise statement of the geography, geology, and history of exploration and the map shows the general structural conditions of that portion of the field mapped and is the best interpretation of the structure which has yet appeared.

[1] "Possibilities of Oil and Gas in North Central Montana," *U. S. Geol. Survey, Bull. 641-C*, 1916.

[2] "Sweet Grass Hills, Montana," *Geol. Soc. Am., Bull.*, Vol. XXXII (1921), pp. 437–78.

LOCATION AND SURFACE FEATURES

The Kevin-Sunburst oil field is located southwest of the Sweetgrass Hills and near the international boundary. The area mapped by the writer extends from Marias River on the south to the Canadian boundary on the north, which includes all or a part of Ts. 31–37 N., Rs. 1 E., 1–4 W., Montana Principal Meridian and embraces an area of about thirty miles east and west by forty miles north and south.

The surface of the Kevin-Sunburst field is a gently rolling treeless plain, dotted here and there by dry lake basins, but is covered mostly by glacial drift. A prominent escarpment or "rim" of Eagle sandstone (basal member of the Montana group) borders the field on the west and north. There are no permanent streams and the rolling topography is the result of the ice invasion during the glacial period.

FUEL AND WATER

The discovery well in the Kevin field was drilled with coal hauled from the Sweetgrass Hills and the second well was drilled with fuel oil shipped in by tank car. Since the first two wells were completed, most of the drilling in the field has been done with crude oil or with gas from the wells drilled in the field. The gas found in the basal sand of Colorado, and from the Sunburst sand of the Kootenai, probably will furnish sufficient gas for the drilling of future wells.

Since there are no permanent streams in the field, rain-water for drilling has been stored in ponds made by damming gullies and coulees. This source has furnished enough for the early development, but if an extensive drilling campaign is undertaken, as seems probable, more dams must be constructed or water must be piped into the field from some permanent source. An ample supply of water may be obtained from the Sweetgrass Hills, the Eagle "rim" west of the field, or from Marias River. It would require a pipe line from twenty to twenty-five miles long to bring the water from the first two sources and about thirty miles to bring it from Marias River to the center of the field. The water problem is now serious but will grow more so unless relief is obtained from one or more of the sources just mentioned.

The field is easily accessible by railroad and fair wagon roads. The main line of the Great Northern Railway borders the field on the south and passes through Shelby, the main town. A branch road of the Great Northern from Great Falls to Sweetgrass traverses the west side of the field, passing through Shelby, Kevin, and Sunburst, which are the main distributing points for supplies and field equipment.

GEOLOGY

GENERAL STATEMENT

The geology in the region of the Sweetgrass arch is difficult to interpret properly because of the glacial drift which conceals the consolidated rocks. Many misconceptions, professional and otherwise, are extant concerning the folding of this uplift and the relation of the Kevin-Sunburst dome to the main arch. It is impossible at this time to write definitely on the folding involved in the area commonly called the Sweetgrass arch but a few suggestions may assist in finally working out the details.

STRATIGRAPHY

SURFACE ROCKS

Glacial drift.—The drift covers most of the surface and conceals the underlying consolidated rocks, so that only scattered exposures can be found. The drift consists of sand, gravel, boulders, and clay and reaches a thickness in places of about 100 feet.

Two Medicine formation.—The greater part of the Two Medicine formation, of Upper Cretaceous age, has been removed by erosion. The remaining part is composed of greenish shale, at the base, followed above by a succession of cross-bedded sandstones and greenish-white shales.

Eagle sandstone.—The Eagle sandstone, Upper Cretaceous, averages about 190 feet thick in the Kevin-Sunburst field. It consists of 30 feet of friable sandstone at the top which weathers into soft slopes; a 95-foot ledge-making sandstone, capped by a few feet of ironstone; and at the base another ledge-maker, 65 feet thick, which is capped by an indurated limy sandstone. In places the sandstone forms a single cliff in which the individual members do not stand out.

Colorado shale.—The Colorado shale, Upper Cretaceous, has an average thickness in the Kevin-Sunburst field of about 1,710 feet. It consists mainly of shale, sandy shale, thin sandstone and contains numerous concretions of light-gray and reddish-brown ironstone fossiliferous limestone. Only the upper 960 feet is exposed between the Eagle "rim" and the top of the fold. The details of this exposed portion, together with 500 feet more taken from the diamond drill cores, is shown in graphic form in the well log section accompanying this paper. The key rocks used in mapping were the concretions of limestone and the thin sandstone beds. The most persistent of these and the most easily recognized are as follows: the *Baculites* limestone concretion 190 feet below the base of the Eagle; the yellow lime chert conglomerate 325 feet below the Eagle; the thin sandstone containing small quartzite pebbles 665 feet below the base of the Eagle, and the series of thin fish scale sandstones and coarse quartzite pebble sands 925 feet below the base of the Eagle.

SUBSURFACE ROCKS

Colorado shale.—The lower 750 feet of the Colorado shale is not exposed, but the two diamond drill cores, the Big West (No. 69 on map), and the Troy Sweetgrass (No. 77) have given a better and more complete record of these rocks than could be obtained were they exposed. It will be noted that the lower portion of the Colorado consists of shale, sandy shale, and sandstone, with the percentage of sandstone much greater and the beds of sandstone much thicker than in the upper part. Small flows of gas have been found at many places, but in only two sandstones has this flow been sufficient to be of value even for fuel. These are the "Water sand," of the drillers, which ranges from 210 feet to 280 feet above the base of the Colorado and the "Gas sand" which is at the base of the Colorado. The "Water sand" carries water on the flanks and gas on the top of the dome, and possibly may carry small quantities of oil in some parts of the field. The "Gas sand" corresponds in stratigraphic position to the First sand of the Cat Creek field.

Kootenai formation.—The Kootenai formation, of Lower Cretaceous age, averages about 365 feet in thickness in the Kevin-

Sunburst field. It is composed of vari-colored shale, sandy shale, and sandstone. The predominating colors of the shale are maroon, pink, and green, but some of the well logs fail to note any brilliant colors. Most of the drillers log two zones of red shale, one at the top and the other near the base of the Kootenai. The Sunburst sand which carries the oil in the second producing well (No. 22 on map) of the field is at the base of the Kootenai, and roughly corresponds in stratigraphic position to the Second sand of the Cat Creek field. This sand in the Kevin-Sunburst field is erratic both as to its character and thickness and its oil content. Of the twenty-eight wells completed through this sand, six have been productive of oil, three have produced gas, and twenty have been dry or have had only "shows" of oil. The productive oil territory, to date, from this sand does not exceed 320 acres. In many of the wells the equivalent of the Sunburst sand is logged as sandy shale or sandy limestone.

It is difficult to determine the top of the Kootenai formation from well logs, since the drillers differ in their interpretation of rock characters. By a careful study of all available logs of the field it was found that in the majority of the wells, the first red beds lie not far below the "Gas sand" which is at the base of the Colorado. The top of the red beds is generally accepted as the top of the Kootenai, but in some of the wells drilled in the field, no red is logged, and on that basis there would be no Kootenai even though the well penetrates the top of the Madison. The writer has taken the base of the "Gas sand" or its equivalent as marking the top of the Kootenai. By reference to the well log section of this paper it will be noted that if the top of the red beds were used as a datum for sub-surface mapping, one would develop some erroneous conditions.

Ellis formation.—The Ellis formation, of Upper Jurassic age, averages about 220 feet in thickness and consists of yellowish and greenish shale, sandy shale and thin sandstone, and thin limestone. Immediately below the Sunburst sand is a bright yellow sandy shale which appears to be persistent throughout the field. This key rock appears to be the most logical boundary between the Kootenai and Ellis since at most places where these two formations have been observed at the outcrop there is a striking contrast in the color

as well as in the character of the sediments. Accordingly it is tentatively considered as marking the top of the Ellis. The Kootenai is composed of brilliant colored shales and coarse sandstone and the Ellis is composed of dull yellowish and greenish shale and thin impure limestone. Paleontologists will probably object to drawing a formational contact without fossil evidence, but it is impossible to obtain fossils from the sand pumpings.

Madison limestone.—The Madison limestone, of Lower Mississippian age, is about 780 to 800 feet thick. Where seen on the outcrop as well as in the Troy Sweetgrass well core, the Madison is a dense, massive limestone throughout. In the well core mentioned, a black shale, probably Devonian, was found at the base, below 780 feet of massive limestone. This core shows several feet of cavernous limestone at the top of the Madison which probably corresponds to the "Campbell pay," and at several places the limestone shows fissures and joint planes which contain oil.

The "Campbell pay," so named because Gordon Campbell drilled the discovery well of the field, lies at the top of the Madison limestone or at the contact between the Ellis and the Madison. Of the nineteen wells completed to the "Campbell pay," to date, nine have been commercial oil producers, and ten have been dry with only "shows" of oil.

Between the Ellis and Madison there is a disconformity which, near the Wyoming line, is occupied by the Chugwater, Embar, Tensleep, and Amsden formations. During the long interval of time between the deposition of the Madison limestone and the Ellis formation the top of the Madison suffered considerable erosion, which may be responsible in part for the porous condition of its upper surface called the "Campbell pay."

Devonian.—The Devonian is probably present in the Kevin-Sunburst field, but little is known of its character and thickness. The only information available is from the core of the Troy-Sweetgrass well (No. 77 on map), which shows 463 feet of rocks below the massive limestone of the Madison. This lower portion of the core consists of black shale at the top, followed below by sandy lime and shale containing fossils which, unfortunately, have not yet been studied and identified. The basal 128 feet of the core is logged as

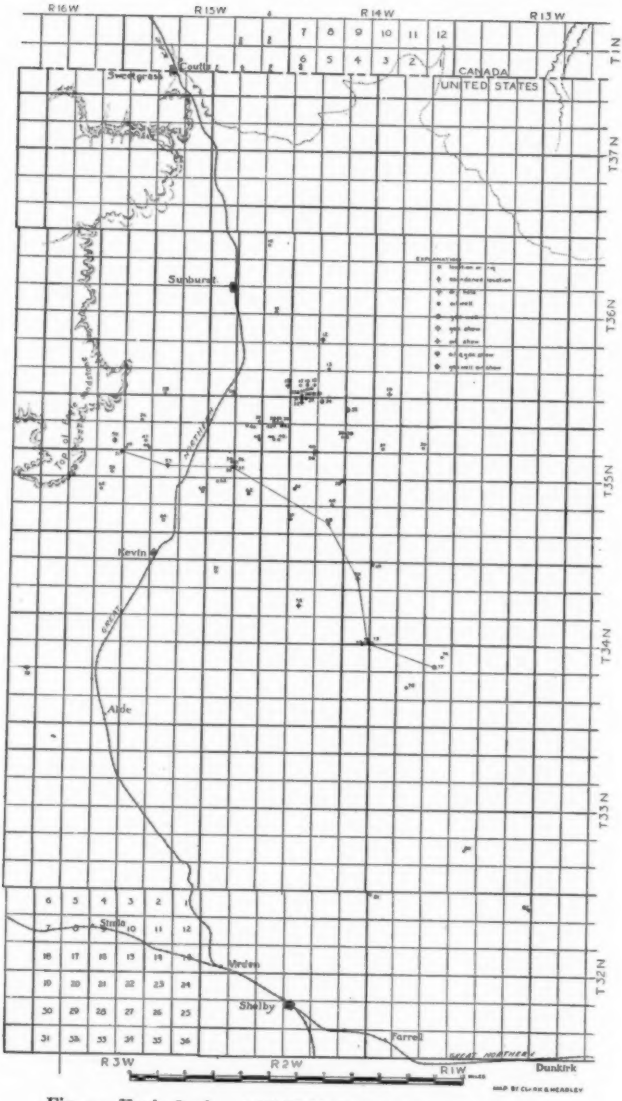


Fig. 1.—Kevin-Sunburst Oil Field, Toole County, Montana

anhydrite but in physical appearance it resembles a partially metamorphosed limestone.

STRUCTURE

REGIONAL STRUCTURE

The Sweetgrass arch is a vast upfold of low-dipping rocks extending in a north-south direction nearly half-way across Montana and is reported to extend for many miles into Alberta and Saskatchewan, Canada. The folding involved was probably induced by lateral pressure exerted during the Rocky Mountain uplift which resulted in the over-thrust faults of the Front Range. Offsetting this lateral pressure from the west was the influence of the Highwood and Bearpaw Mountains and the Sweetgrass Hills on the east, causing the rocks to buckle into the Sweetgrass arch. This arch in Montana was further modified by the influence of the Belt Mountains uplift which induced northward dips and converted what might have been a large southern closure into a northward pitching open fold. The northward dips, induced by the Belt Mountains uplift, probably continue as far north as the region of Marias River, where the influence of the laccolithic Sweetgrass Hills, in part at least, induced the folding of the Kevin-Sunburst dome, or it may be that this large symmetrical dome is, itself, laccolithic in origin.

From the detailed studies in the Kevin-Sunburst field and from general reconnaissance work to the south, it appears that the Kevin-Sunburst dome is the highest point structurally on the main arch, and the largest single closed fold of the Sweetgrass arch in Montana. As pointed out above, the Sweetgrass arch south of the Kevin-Sunburst dome is probably an open fold which, it is believed, contains no closed folds as large as the Kevin-Sunburst dome. While it is to be expected that minor folds and terrace structure are present along the top and flanks of the arch, it is not thought that any folds comparable to the Kevin-Sunburst dome will be found between Marias River on the north and the Belt Mountains on the south, and between Missouri River on the east and the belt of highly disturbed rocks, bordering the Front Range, on the west.

LOCAL STRUCTURE

The Kevin-Sunburst dome is a large low-dipping symmetrical fold, developed along the axis of the Sweetgrass arch. The crown

of the dome is situated in the SW¼ of T. 34 N., R. 1 W., and the major axis trends north north-west and south south-east. The dip ranges from 40 to 100 feet per mile and averages about 50 feet. The known closure is about 700 feet and the area above or within the lowest closing contour is about 700 square miles.

A number of minor closed folds, terraces, noses, and structural re-entrants are present along the flanks of the main dome within the lowest closing contour. The Kevin-Sunburst dome has been classified as a cross-fold, but the writer cannot agree with such a classification because the dome is really the major fold of the Sweetgrass arch in Montana, and its axis coincides with and trends parallel with the axis of the main arch.

Ice squeezes induced by pressure and cracks in the ice sheet together with local shale slumps have been mistaken and mapped for faults. Data so far collected lead the writer to believe there is no faulting of appreciable magnitude in the Kevin-Sunburst field.

RESULTS OF DRILLING AND THE OIL PRODUCING ROCKS

The first well in the Kevin-Sunburst field (No. 79 on map) was drilled about 1912 on the James Miller ranch in Sec. 25, T. 34 N., R. 3 W., and reached a depth of 1,755 feet which penetrated the Madison limestone to a depth of 75 feet below the "Campbell pay," without commercial production. Several small flows of gas were struck in sands of the Colorado shale.

The second well in the field (No. 51 on map), located in the NE corner of Sec. 16, T. 35 N., R. 3 W., was completed by the Gordon Campbell-Kevin Syndicate in March, 1922, when commercial production was reported at a depth of 1,771 feet. This was the discovery well of the field and found oil at the top of the Madison limestone, or the "Campbell pay." Several small flows of gas were reported in sands of the Colorado shale and the basal sand of this shale yielded sufficient gas for the camp and the drilling well. Some gas was reported from the Sunburst sand and a showing of oil was reported from the middle of the Ellis formation.

The third well in the field (No. 22 on map), located in the SE corner of the SW¼ of Sec. 34, T. 36 N., R. 2 W., was drilled in on

June 5, 1922, by the Sunburst Oil and Gas Company. Commercial oil production was obtained in the Sunburst sand at a depth of 1,545 feet. The top of the sand was reached at 1,535 feet and the bottom at 1,565 feet. After producing for four months, this well is making about 35 barrels per day.

Since the completion of the first two productive wells in the field, development has been active, and to date, October 18, 1922, twenty-eight wells have been completed, with fifteen commercial oil wells and two or possibly three commercial gas wells.

Of the twenty-eight wells drilled into or through the Sunburst sand, six (Nos. 15, 20, 21, 22, 23, and 33 on map) are commercial oil wells, and two (Nos. 34 and 35) are commercial gas wells, No. 34 making 2,250,000, and No. 35, 1,250,000 cu. ft. per day, when first drilled in. It is estimated that the oil wells from the Sunburst sand will range from 30 to 100 or 150 barrels per day, initial production. The oil productive territory in this sand which has to date been fairly well defined by dry holes on the southwest, west, and northwest, does not exceed 320 acres, lying mostly in Sec. 34, T. 36 N., R. 2 W., and in Sec. 3, T. 35 N., R. 2 W. About the only chance for an extension of this production is to the northeast and the southeast, but such extension seems rather doubtful. The first wells in the sand appear to be holding up well, considering the small productive area and the absence of water pressure. The small initial showing, however, does not condemn this sand over the whole dome and it is reasonable to expect that other small pools may be found in it in the Kevin field.

The results of drilling to date indicate that the "Campbell pay" is the most promising oil-bearing rock in the field. Nineteen wells have been completed to this "pay," with nine commercial producers and ten dry holes or wells with mere "showings" of oil. The productive wells (Nos. 13, 41, 51, 52, 55, 59, 61, 68, and 74 on map) are scattered over an area ten miles north and south by nine miles east and west and are all wildcats, there being no offsets drilled in. Each of the dry holes (Nos. 12, 14, 18, 32, 50, 70, 72, 77, and 79 on map), with the exception of No. 50, is greater than one mile from any of the producers and about one-half the dry holes appear to be outside wells.

The wells producing from the "Campbell pay" are not large and probably range from 20 to 125 or 150 barrels per day initial production. None of them have been pumped long enough to indicate the rate of decline.

The apparent lack of uniform water pressure is one of the disturbing conditions in this field. Of the wells completed in the field only one (No. 12 on map) has shown considerable water, but it is the lowest well structurally yet completed to the "Campbell pay." The log shows oil, gas, and water at 1,875 feet and more gas and water at 1,877 feet. The gas and water pressure was sufficient to throw the fluid over the crown block when first drilled in. The percentage of oil in this well was so small that it is doubtful if it can be operated at a profit. Other wells which met more or less water are Nos. 14, 18, 51, 53, 68, and 70, which give more or less water distribution through a structural elevation of about 425 feet, indicating the probability that the oil and whatever water may be present lies in pockets or pools where the "pay" is porous enough to hold commercial quantities, without free circulation between these pools.

Three important tests (Nos. 80, 81, and 82 on map) now under way in the southern end of the field appear to have fair chances of getting production. If these wells obtain commercial oil, it will extend the possibilities of the field to double the present prospects.

GRADE OF OIL

There is considerable difference between the oil from the Sunburst sand and that from the "Campbell pay," the former being lighter

Constituents	Sunburst Oil and Gas (Per cent)	Campbell (Per cent)	Gladys-Belle (Per cent)
Sulphur	1.04	1.65	.....
Gasoline and naphtha (approx.)	30.9	2.3	25.0
Kerosene (approx.)	18.4	19.4	15.0
Gas oil (approx.)	10.2	16.5	20.0
Wax distillate	.....	.....	25.0
Residue	10.5	9.4	15.0
Light lubricants (approx.)	6.4	8.1	.....
Medium lubricants	5.9	15.3	.....
Viscous lubricants	5.4	.....	.....
Gravity, Baume	35	30	31.7

and containing more gasoline. The foregoing analyses will show the grade of the oil from three wells which probably will represent fairly the oil from the two producing rocks.

The analyses of the Sunburst Oil and Gas Company and the Campbell oils were made by the Bureau of Mines, except the gravity which was taken from United States Geological Survey press notice. The analysis of the Gladys-Belle oil was obtained from their field manager.

SOURCE OF THE OIL

It has been postulated that the oil found in the sandstones of the Kootenai at Cat Creek and at Kevin is indigenous to this fresh and brackish water formation. This has not been proved or disproved but the writer is inclined to believe that the oil found in the Kootenai of Montana has migrated, from the enclosing formations or elsewhere into the Kootenai sandstones, which merely act as reservoirs.

The many faults in the producing area at Cat Creek admit of a more or less free circulation of oil and water which results in commercial oil accumulation on the structural "highs." In this field it appears that upward migration along these fault planes or other fractured zones is responsible for commercial oil accumulation in the "Cat Creek" sandstone at the base of the Colorado shale and in the "Second" sandstone of the Kootenai. The character of the oil indicates that a part of the original constituents may have been left behind through a process of natural refining or filtration.

The quantities of oil found in the Kootenai in the Kevin field appear to have migrated upward from the marine Ellis shales and limestones below, into the basal sandstone of the Kootenai which is merely the normal migration from shale into sandstone. It is possible that the Sunburst sand (Kootenai) production originated in the Madison limestone, but it is improbable that oil would migrate through the total thickness of Ellis, except along faults or fractured zones which are not apparent in the Kevin field. The Kootenai, where studied at the outcrop in Montana, contains few if any visible plant or animal remains, but a very close study may show sufficient microscopic organisms to produce commercial quantities of oil, though this is doubtful. The Ellis is of marine origin, containing

many visible fossils, and it is the most likely source for the oil found in the Sunburst sand.

The oil found in the "Campbell pay" in the Kevin field most probably originated in the Madison limestone. Pressure and some water circulation probably induced upward migration of the oil from the main body of the limestone into its upper more or less cavernous portion. Here the oil gradually accumulated for the reason that further upward migration was prevented by the relatively impervious sandy limestone and shale at the base of the Ellis.

THE OIL INDUSTRY; ITS IMPORTANCE AND SOME OF ITS PROBLEMS

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The United States produces approximately 62 per cent of the world's crude oil. Its production for the year of 1922 was about 550,000,000 barrels. In the oil industry in this country there is invested about $8,000,000,000, an amount almost equal to the foreign debt to this country arising out of the late war, and which some of our generous fellow-citizens are in favor of canceling. By various and sundry methods, it would seem that a great many people in this country are in favor of eliminating this investment also.

Since 1859, the "year one" of oil in these United States, the growth of the business has been phenomenal. Each succeeding ten years have produced more oil than the entire preceding period since the discovery of oil. The production of oil from 1900 to 1923 has increased nearly 800 per cent, and at this time we have the greatest production of our history, amounting to over 1,700,000 barrels daily. This oil is produced from approximately 282,000 wells.

During the year of 1923, there will be manufactured and used from crude oil and gas about 180,000,000 barrels of gasoline, and 50,000,000 barrels of kerosene. Most of this gasoline will be used in 12,000,000 motor vehicles. If the world were to be deprived of gasoline, and the lubricants made from crude oil, it would be turned back a quarter of a century. More than that, we have become so dependent on these, that our whole industrial development might be said to revolve around oil. This generation is without training in the ways of our forefathers in doing our tasks in their more primitive manner. "Oil" is not only now one of our very great industries, but is becoming of greater relative importance every year.

We have had many calamitous predictions of its early exhaustion, but if we are to judge its future by its past, it will be but a few years until the annual production of oil will reach 1,000,000,000 barrels, and it may even then be in the swaddling clothes of infancy. Never yet has the oil producer failed to bring forth the hidden deposits of this invaluable commodity when needed, and a fair prophecy is that they will not fail, until some other substitute is found that will better fulfil the requirements of the times.

One would think that an industry of such supreme importance to our civilization would receive the consideration from all our people to which it is entitled; but if we are to form our conclusions from the tirades against the industry which have been made by some of the near statesmen in our legislative halls, and by the tax measures to which the business is unjustly subjected, it would appear to be an illegitimate business, and one to be penalized. It is to a few of the causes of this unfavorable attitude toward the oil industry that attention may be directed here.

The first of these is the ignorance of the public as to oil. The public in general has but little conception of the oil business as it really is. It hears of the gusher wells, and of the fortunate ventures, and generally exaggerated accounts of these, but it does not know that the 1,000-barrel wells are usually greatly magnified as to size, or that they do not last long as such; it is not advised as to the much greater number of small wells drilled, or of the dry holes, which add so much to the costs of the operator. The public does not know of the money spent for equipment, for labor, for leases and lease rentals, nor of the manufacturing and marketing costs; and, as a result, it cannot see why gasoline and other products of crude oil should cost so much.

There were approximately 23,000 wells drilled in the United States during the year 1922. Accurate figures as to the cost of these cannot be obtained. One company operating exclusively in Oklahoma, with average drilling conditions, drilled, scattered over different parts of that state, twenty-four wells in 1922, costing a total of $552,232, or $23,022 per well. In these wells, it drilled a total of 67,844 feet of hole, or an average depth of 2,827 feet per well,

and at an average cost of $8.14 per foot. This included labor, fuel and water, casing, rigs, etc.

Oklahoma operators drilled by far the greatest number of wells in 1922. In some states the drilling was at a less depth, and less costly, but in others, such as California and Texas, the costs were much greater. It is probably a fair assumption that in using costs in Oklahoma as an average, there will be no exaggeration in the results, and by doing so and using the average of the one typical company cited above, we have the following figures:

Total number of wells drilled in U.S. in 1922, estimated	23,000
Total number of feet drilled in these wells, estimated	65,021,000
Total number of miles in depth, estimated	12,315
Total cost of drilling, estimated	$529,270,000
If we add cost of lease equipment, expenditures, etc., estimated	50,000,000
If we add cost of lifting 550,000,000 barrels at 30 cents, estimated	16,500,000
If we add lease bonuses paid, etc., estimated	100,000,000
If we add lease rentals paid to landowners, estimated	15,000,000
If we add value of one-eighth royalty to landowners, estimated average price received for oil produced at $1.35	92,562,000
If we add overhead charges on all field work and equipment of 5 per cent, estimated	30,941,000
This gives a total cost for the 550,000,000 barrels of crude oil produced in the U.S. in 1922, estimated	$834,273,000

An average of all the markets in the various fields brings the total value of the oil produced in the United States in 1922 to approximately $775,000,000, which amount the producer would receive for this oil that cost him $834,273,000, estimated as above, and the net result is a deficit in the producing end of the oil business for the year 1922 of over $59,000,000. These figures are probably not exaggerated, although they are necessarily estimates. They apply strictly to the production end of the business. Some companies and individuals have made a profit from the production of oil in 1922, but many others have lost money. The cost of the barrel of oil produced is the *average of the entire cost of all* operations and the things incident thereto.

It may be contended that the larger companies get undeserved profits out of other branches of the business. As the Standard Oil Company, of New Jersey, is probably the company most frequently cited as one which has taken from the public too much profit, and as this company is engaged in all branches of the industry, producing, pipe lines, refining, and marketing, a few figures showing an analysis of its statement are important. In the past five years this company earned a total annual average of $80,000,000 on an average invested capital for that time of $600,000,000, or at the annual rate of 13⅓ per cent. It has always pursued the policy of keeping a large part of its earnings in the business, and, as a result, it is able to help meet the demands of the industry in a manner that can only be met by a very large amount of capital invested in refining and marketing facilities. Were it not for the ability of a few large companies to absorb much of the overproduction during such periods, and to supply the demands of the public during periods of underproduction, both the producing oil industry and consuming public would be facing demoralization most of the time.

There are hundreds—probably thousands—of industries and institutions scattered throughout the United States, which have from year to year earned more money per dollar of investment than has the Standard Oil Company, of New Jersey. It is not infrequent for banking institutions to earn 40 per cent on their capital, or for manufacturing interests, and their accomplishment is highly commended by the localities in which they are located. They generally have a mere handful of stockholders; but if one of the great oil companies, with thousands of stockholders, makes half as much on their investment, it is a subject for investigation at once.

Yet the business of producing, manufacturing, and marketing oil is not only essential to our very national existence, but, on the average, is much less profitable than in the instance of the company cited.

A second thought concerns the attitude of the politician toward the oil business. There are at least three kinds of politicians in our executive and legislative positions. There is the fair-minded, able, and conscientious man who is trying to do his duty by all the people, without fear or prejudice, and who can generally see what

this is and does it. In the hands of this man, the interests of the rich and the poor alike are safe. If all officials were of this type, the best interests of the entire state and nation would be well served.

Another type is the honest, but uninformed and narrow-minded man. He is impractical as to business; he is easily influenced by the demagogue; he does not understand that there is any obligation to capital, or that protection of capital is necessary to secure its employment, as well as is the protection of labor; or that the prosperity of the one is dependent upon the prosperity of the other. This man may develop if his position is taken from ignorance; but he may do a lot of harm to his constituents during his period of incubation.

The third type is the demagogue who is willing to accomplish his own purposes, regardless of the ultimate results to the state. He will use any argument, take any position, take advantage of any statements whether they represent the facts or not, that will influence or strengthen his position. We have these men in public life in both state and national politics. They are a menace to the public interests. They keep themselves in power by handing out special privileges, which may or may not be needed, but which would not be tolerated if these same constituents were asked to pay for them by direct taxation. They do pay for them in the end in the increased cost of everything they buy.

In Texas, for instance, the favorite panacea for every legislature for years past, whenever a deficit is faced, is to get the money from the oil people. The excuse urged is that the oil industry is taking the natural resources of the state and using them at a great profit, and that the oil produced gets out of the state and escapes the ad valorem tax; and that the industry takes from, and does not add to, values. This is not true. In 1922, Texas produced about 115,000,000 barrels of oil. On January 1, 1923, there was in storage within the state between 50,000,000 and 60,000,000 barrels of oil, all of which will be taxed for ad valorem purposes. If we consider the additional amount of oil that was consumed within the state, some of it thus turned into other character of property, it is safe to say that the ad valorem tax on oil has not been neglected.

Oil does add to the taxable values. In Eastland County, in 1917, the assessed valuation of all property was $11,000,000. Many of the people of the county were leaving. They could not sell their farms. They were discouraged and broken. Oil was found, with the result that in 1920 the assessed values in the county were $58,000,000, and this was the result of the investments in connection with, and arising out of, the development of oil. No better farming conditions have existed than in 1917, and no other industry has developed. Yet Eastland County, Texas, has on the whole been a very unprofitable venture for "oil." Millions of dollars more have been spent in that county by the oil operators than can ever be expected to return to them. Those who have made a profit out of oil in that county are the rare exceptions.

In the state of Texas there are 37 counties classed as oil-producing or oil-manufacturing counties. Out of 257 counties in the entire state, these 37 counties paid 48.27 per cent, and the remaining counties, to the number of 220, paid 51.73 per cent of all the property taxes in the state of Texas for 1922. In addition to this, the oil production of the state paid approximately $2,500,000 for the privilege of adding these additional values to property.

In the same year that Texas produced about 115,000,000 barrels of oil:

The oil industry paid in wages	$113,943,000
It paid in lease rentals	4,103,500
It paid in lease bonuses	24,752,500
It paid in royalties, over	16,000,000
In addition to its ad valorem taxes, it paid into the state, special taxes amounting to	3,574,000
It employs about 55,500 men and women, at an average per year per employee of over	2,000
On the whole, the oil industry spent in Texas in 1922 a sum amounting to over	165,000,000

The experience of Texas has not been unlike that in other states, varying only in degree. It is only through the fairness of the goodly number of the first class of politician, and of the second class when they become better informed, that the industry has escaped some most destructive tax measures.

We have had proposed, during the past years, taxes on about every conceivable transaction that oil might make, from that of one year which called for 2 per cent on production and thereafter 2 per cent on the value of the oil on each turnover, or a total of 10 to 12 per cent (which was probably the most extreme bill suggested), to 5 per cent on production and 2 cents per gallon on gasoline proposed this year; and this is a legitimate and necessary business.

Another menace to the business is the unscrupulous promoter. Anyone who can stop this thieving will be a world-benefactor, and will do the oil business a favor the value of which is difficult to estimate.

It is estimated that hundreds of millions of dollars annually are taken from the portion of the public that can least afford to lose it by these crooks. If the investors could but see the inside workings of these manipulators, the deliberate stealing and parceling out of the money received from their gullible clients, they would conclude at once that here was one class of citizens fit subjects for the K.K.K. to operate on, as the government officials, either from the legislative, judicial, or executive branches, or from all of their faults combined, have wholly fallen down in protecting the public from these pirates who call themselves men.

At the present time, their field of operation is chiefly in Arkansas, and their transactions are based on the Smackover field. Guaranteed dividends of 100 to 400 per cent are their stock bait, and if they fail legitimately to earn the promised dividend —and nine out of every ten do and will fail—a fake transaction is ribbed up to keep them out of jail. The joker is usually that the investor is advised that the promised dividend has been declared, and he is asked if he wants the money, or if he would prefer to double it up, or multiply it, by reinvesting. The result is that none, or very few, take their money, and just as certainly as they do not, they never will get it. The efforts of these promoters are chiefly to sell stock, to get the money, and keep out of jail. It is said that one of these concerns is taking in $10,000 daily, others $2,000 daily, and up, and that they are all financed by one or a few men.

There is not an experienced oil man in the United States who does not realize the frauds that are being perpetrated in the name

of oil, and not an honest one who would not do everything possible to prevent the same. The most regrettable part is the fact that it is the poor class of people, and people of small capital so necessary for their living, that are taken in by these, sometimes losing the savings of a lifetime, their provision for old age, or for the education of their children.

One would think it impossible that an advertisement promising 100 to 500 per cent dividends would fool anyone. Why pay good money to sell for one dollar something guaranteed to pay five? Such things are not done honestly, and on their face should be a warning to the public. If the public only had the facts, they would find that from 50 to 90 per cent of all the money taken in by these syndicates is spent or stolen for promotion profits.

Newspapers are usually published by practical men who know and should be able to analyze a business proposition. They have the ear of the public and do more to create sentiment and form the opinions of the public than any other agency. The public is their client and their living. The vast majority of their readers are people of small means, and probably of limited business acumen, yet these same clients are defrauded of amounts estimated at hundreds of millions of dollars annually by the same newspapers carrying, for pay, advertisements which they know to be fraudulent and are thus guilty of betraying their own clients whom they pretend to protect. Happily there are some papers who do not stoop to this degrading practice, but they are too few.

Attention should be called to another characteristic of this same part of the press: They are the first to criticize legitimate enterprise, and to impute wrong motives of sensational character, which the liberty of the press allows them to do with impunity, but which they know, or could find out, to be untrue with a little diligent search on their part.

Another method by which these promoters get by—and again by an abuse of confidence—was told by one of their stock salesmen. This is through the use of information furnished, for a consideration, by the men in whom the people are entitled to have the greatest confidence; another case of selling out their clients. This individual was asked how he succeeded in selling his worthless

stocks. He explained by giving his own experience. His territory was in a certain state which he named. Going to a small town bank, he made an arrangement with a member of the bank for a commission of 20 or 25 per cent to furnish him with a list of his depositors whose notes he would take, and for what amounts. The stock salesman would then canvass these names, sell to them his worthless stock, take whatever cash payment he could get, and the balance in a note; would take these notes to the banker and discount them, pay the banker his commission, and move on to the next town. The banker, of course, would not be known in the transaction except when the note became due, and then only as the holder of his customer's note, which he could explain that he was always willing to take. A banker who would do this to his customers deserves to be classed with Judas Iscariot. No reputable banker would stoop so low, and most bankers are reputable.

Still another method of operating, adopted by some of these same promoters, is to use the names of men of wide public reputation. Sometimes these names are used without either the knowledge or consent of the owner, others through a misunderstanding, or through misinformation; but some permit the use of their names for a consideration, knowing that the only purpose is to influence prospective investors. It is said that in England a good living is often made by some titled persons in this manner. In our own country sometime ago, two ex-United States senators headed two promotions in oil as the presidents of these two companies; both of which propositions were wholly impractical and probably organized for their stock-selling value to their promoters. Both companies were total failures to the purchasers of the stock. One of these ex-senators is said to have admitted openly that he had told the promoters he had neither money nor experience to put into the business, to which they replied, "Some men's names are worth more than money or experience." He thus deliberately admitted he was willing to have his name used to influence people who believed in him to invest their money in a proposition the merits of which he knew nothing. This man was nationally known and respected as a leader of the so-called common people and of the farmer element of our country, and he achieved his fame largely by denunciations of business and

corporate interests. In the same capacity today he would be typical of those who denounce large and successful interests on account of the profitable business they are conducting, and for the salaries they pay to their officers who conduct the business ably and profitably.

The backbone of all of our material prosperity is the successful operation of many large enterprises. If these fail, labor is out of employment, farmers cannot sell their products, merchants go into bankruptcy. Smaller business of every character is more or less directly or indirectly dependent on the able and successful operation of our railroads, our steel mills, shipping, oil and other mining interests. Experience has shown that a $100,000 yearly salary is economical over one of $5,000 for the same job, if, by the larger salary, a better executive can be obtained.

It is my judgment that this applies to all walks of life, and that salaries of $15,000 to $20,000 yearly for our judges and higher public officials, to attract better men to these positions, men who in private life earn probably twice these amounts, would be the greatest saving we could make, and there would be a saving to the very element of our communities who are preventing these reforms on the score of extravagance. Fewer and better officials are what we need. Pay them more and we can get such men to serve, although even then at a sacrifice.

Did you ever notice that the man who criticizes most generally criticizes success, yet is himself the least successful of all? He probably is also on the sucker list of a fake oil promoter, and has already been stung.

Just another reference to fraud: I hope there is no geologist who would sell himself or his noble profession to advance any fraudulent operation. If he does, he is no better than the crooked promoter, the false newspaper, the unworthy politician, or the greedy banker, who, for the personal gain, sells himself and sacrifices his honor to the end that those who have a right to believe in and depend on him are defrauded and impoverished. If our politicians and our newspapers spent half the effort to protect the public, their clients, against these frauds, that they spend in attacking success, the entire population would be greatly benefited. What

we need most in the oil business is more education of the public as to what the business really is, and what is, and what is not, the real oil business. We should help to warn the public against all forms of fake promotions, and assist the officials in eliminating these. With a strict insistence on the part of your organization that your members refuse to aid in any manner, directly or indirectly, these promoters in their stealings from the public, a great step forward will have been taken toward eliminating them, and the reputation of the oil business will also be immensely bettered thereby.

The honest oil operators owe to themselves and to the public the duty of assisting in every proper manner, in bringing to an end these misrepresentations of a legitimate business. Every honest legislator and every executive whose duty it is to protect the public against fraud, thus owes it to his constituents to perform a duty which has long been neglected, and should have your co-operation and that of the legitimate operator. With the elimination of the faker from the business, the public will have a better appreciation of oil, of its employees, and of its problems, and will have more faith in its integrity.

I have great faith in the geologist, and I believe they are "day by day in every way getting better and better," and I want to congratulate this organization in that it is already on record against any practices by its members that would assist these promotion schemes. I have also great faith in the oil business and in its future; and in the American public. I believe that when people once learn to know the real oil industry, and to discriminate between it and the fakers who misrepresent the business, they will insist on a square deal to the great and wholly legitimate industry.

GEOLOGICAL NOTES

A THEORY TO ACCOUNT FOR OCCURRENCE OF OIL IN THE VESICULAR CAVITIES OF IGNEOUS INTRUSIONS

The prospector for gold working in a new and unexplored region eagerly pans the stream's gravels for traces of the yellow metal, knowing that a little gold in the stream channels may indicate the existence somewhere in that region of a vein that will pay to mine. In the same way a petroleum geologist, investigating an area far removed from oil production and containing sandstones and shales of untried and unknown oil possibilities, is also eager to find traces of petroleum. The region in some way seems a little more promising if nature with the materials on hand has been able to produce some real live oil.

In 1919 the writer was in charge of an investigation of the oil possibilities of the west half of the state of Oregon and in only one place was any live oil found. This oil of about the consistency of vaseline was found filling the small cracks and vesicular cavities in an igneous intrusive sheet. This intrusion overlay a thin bed of black shale in the thick Tyee sandstone member of the Tertiary. Since that time the writer has seen a number of dikes in southwestern Colorado where a light oil filled the vesicular cavities of the intrusive. These dikes containing oil occur in the Mancos shale of Cretaceous age.

These occurrences of oil in Oregon and in southwestern Colorado have been described in geological reports of the regions and in attempting to account for it the suggestion has been offered that the oil had originated in some of the deeper and older formations and in working its way up alongside of the intrusions had, by great pressure, been forced into the cavities in the intrusion.

A series of experiments carried out in a testing laboratory in Los Angeles seem to give a simpler and possibly a more exact explanation of oil occurrences in igneous rock. The testing laboratory was attempting to produce a concrete pile which would have all of its voids filled with asphalt and in that way be waterproof and impervious to the destructive salts of ocean water.

The first experiments were made by immersing a concrete block in a bath of hot asphalt and subjecting this to great pressure in order to force

liquid asphalt into the voids of the concrete. It was found that the asphalt could only be forced in a short distance, and then doubtless the pressure of the air contained in the voids gradually became sufficient to resist the further entrance of the asphalt. This experiment seems to open a serious objection to the explanation that the oil found in igneous rock was forced into the cavities by pressure.

The experiment which was finally successful and is now being made use of commercially for the water-proofing of concrete piles was as follows. The concrete block was made up and aged under water so that all of its voids were water-filled. This block was then placed in a bath of melted asphalt and the temperature raised to a point somewhat above 212° F., the boiling point of water. At this temperature the water left the concrete in the form of steam. The temperature of the bath was then lowered and the voids of the concrete which formerly had been water-filled became partial vacuums. It was found that with these vacuums to give suction the liquid asphalt was readily drawn into the very center of the concrete block and filled all of the voids.

The above method of filling the voids of concrete with asphalt, it seems to the writer, might have been duplicated in nature in the filling of the cavities of an intrusion, only in this case the heat of the intrusive distilled the oil which later filled the cavities. The intrusion as it forced its way into the sedimentary formations would by its heat distil water into steam and hydrocarbons into gas or oil. Some of the gas would enter the molten rock and form the vesicular cavities in the intrusion itself. Due to the force and heat of the intrusion there would be unbalanced rock pressure for a time. Then, as the entire intrusion cooled it would be more or less broken by fine contraction cracks and every vesicular gas bubble on becoming cool would be a partial vacuum. If this intrusion had penetrated a water-filled sandstone, then as it cooled, water would be sucked back to fill the contraction cracks and cavities and this water, hot and under great pressure, would doubtless account for the vesicular cavities so often filled with quartz, lime, or other crystals. If, on the other hand, the intrusive had penetrated a shale containing hydrocarbons, capable of being distilled into petroleum, at a certain distance from the molten rock the temperature would be just right to produce oil and when the intrusion cooled the oil would be sucked back and would fill the voids in the rock.

This explanation seems to be well borne out in southwestern Colorado. There intrusions cutting the Dakota sandstone, a good water sand, have their cavities filled with quartz or lime crystals and the intrusions cutting the Mancos shales have their cavities filled with oil.

The writer believes that due to the suction created as the igneous rock cools and the unbalanced condition of rock pressure during cooling, the filling of the voids in the intrusive is certain to take place within a very short space of time after the intrusive begins to cool. He further believes that such oil did not have its source in some deeper sedimentary beds, but is actually the distilled product of the beds found in contact with the oil-saturated intrusive.

As stated at the beginning of this paper, the petroleum geologist working in new and untested regions is anxious to see some traces of real oil. Igneous intrusions may often be helpful in furnishing such evidence and in identifying certain shales which may be regarded as possible sources of oil.

CLARENCE B. OSBORNE

LOS ANGELES, CALIFORNIA

RADIOACTIVITY AND OIL FIELD LOCATION

The application of radiometric surveying to the discovery of oil deposits is advocated by a Russian geologist, L. N. Bogojavlensky, in the last number (No. 2) of the *Petroleum and Oil Shale Industry Magazine*, just issued by the Soviet Council of the Petroleum Industry. The method proposed by the author is based on the varying concentration of radio elements in the earth's crust. After the value of air conductivity at different points is determined, it is, he says, possible to construct curves ("isorads") connecting the points of equal intensity of the earth's radio activity; thus delineating the radio-active body or area. "An accumulation of radio elements in the earth's crust may be due to radio-active ores and minerals, or to gases containing emanations, or to emanations dissolved in either water or natural organic liquid, such as petroleum." As compared with water, oils are stated to possess a greatly superior power of absorbing radio-active emanations, the petroleum absorption being 45 times that of water. He concludes that "every oil deposit, even in sedimentary rocks, must have a greater radio activity as compared with that of the inclosing rocks." The examination of the article shows that his conclusions are based upon radiometric surveys in areas of mineral springs, so that, as pointed out by Kalitzki in the succeeding article of the magazine, the assumption by the author that the contours of oil deposits may be represented by simply determining the radio activity on the earth's surface appears somewhat premature and remains to be proved through test demonstrations of the method in oil pools of differing depth and configuration. Whatever value may be

found in the speculative proposal of Bogojavlensky, the idea is calculated to stimulate the thought of oil geologists, and that it always a profitable thing.

DAVID WHITE

THE CARBON RATIO

Considerable verbal criticism has been made in recent years of the "Relation of Oil to Carbon Ratios of Pennsylvanian Coals in North Texas" by Myron L. Fuller, published in *Economic Geology*, Vol. XIV, No. 7, November, 1919. It is the purpose of this correspondence to call the attention of the petroleum geologists working in North Texas to the application of the theory since it has a sound foundation and has for four years held true to the predictions made by Mr. Fuller.

It has occurred to the writer that a greater part of the criticism has been made without a comprehensive study of Mr. Fuller's paper. To date, there have been few, if any, exceptions. The Nocona gas field of Northern Montague County lies between the 60 and 65 isovolves. For this district Fuller predicted "Commercial pools rare, but oil exceptionally high grade. Gas wells common but usually isolated rather than in pools." The Gulf Production Company's Worsham well, near the center of the east line of Clay County, is producing high gravity oil and is located between the 55 and 60 isovolves. Fuller notes that between the 55 and 60 isovolves are "the principal fields of light oils and gas in the world." Recent developments in the other counties of North Texas have not disproved the applied theory.

The Brock oil field, southwest of Ardmore, Carter County, Oklahoma, has been spoken of as disproving the carbon ratio theory. As a matter of fact, its position is between the 55 and 60 per cent isovolves, the oil is of high gravity, and the field is of small areal extent.

WILLIS STORM

RED BLUFF, CALIFORNIA

SERICITIZATION AND DOLOMITIZATION COMPARED WITH THE FIXED CARBON RATIO OF COAL AS INDICES OF METAMORPHISM IN OIL-BEARING FORMATIONS

At a recent informal gathering of geologists in Dallas, the question was raised as to whether any metamorphic rock properties other than the fixed carbon ratios of coals could be used in the same general way as the fixed ratios, to judge of the petroleum possibilities of a given rock forma-

tion. Since this is a subject which has undoubtedly arisen in the minds of many of us, a few remarks may not be amiss here.

The fact that a more or less definite relation exists between the character of petroleum in its native state and the degree of metamorphism to which its containing rock formation has been subjected was first described by David White,[1] and was later rather fully described by M. L. Fuller with especial reference to Texas and Oklahoma.[2] These gentlemen showed that where coal and petroleum are present in the same formation, the higher the fixed carbon ratio of the coal, i.e., the more completely the coal has lost its original volatile hydrocarbons, the lighter is the gravity of the petroleum. The alteration of both coal and petroleum is no doubt closely related to mechanical causes and effects within the rock formation. Static compression, differential shearing, and fracturing must be factors of more or less importance in the process.

Elsewhere[3] we have shown that one of the earliest, if not the earliest, of new minerals to form in a sedimentary rock subjected to dynamic metamorphism is sericite, provided the requisite constituents for its makeup are present in the original rock. In very slightly altered mudstones and impure sandstones this sericite, occurring as a fine, silky mica, is therefore an index of incipient metamorphism. With further alteration, other changes are observed.

The question in hand boils down to these terms: In a sedimentary formation containing coal, petroleum, and the necessary constituents to produce sericite, what fixed carbon ratio is equivalent to the first appearance of sericite? We have looked into this problem rather extensively, although not exhaustively, and have found that sericite is commonly not developed in a sedimentary rock, capable of producing this mineral under suitable conditions, until after the fixed carbon ratio of any associated coal has reached a high value, higher than 65°, which marks the approximate limit beyond which a formation is not likely to yield commercial oil production. In other words, the mineral index of lowest dynamic metamorphism in ordinary sediments cannot be used, in the absence of coal in the formation, as a guide to the possibilities of obtaining oil in commercial quantities.

[1] "Some Relations in Origin between Coal and Petroleum," *Wash. Acad. of Sci.*, Vol. VI (1915), pp. 189–212.

[2] "Relation of Oil to Carbon Ratios of Pennsylvanian Coals in North Texas," *Econ. Geol.*, Vol. XIV (1919), pp. 536–42; "Carbon Ratios in Carboniferous Coals of Oklahoma, and Their Relation to Petroleum," *ibid.*, Vol. XV (1900), pp. 225–35.

[3] Lahee, F. H., *Field Geology* (2d ed., 1923), pp. 254–56.

With reference to using the amount of dolomitization of a carbonate rock as an index of degree of metamorphism and therefore of oil possibilities within a formation, we may point out that dolomitization may have occurred previous to the burial and true lithification of the rock, or through essentially chemical agencies as contrasted with mechanical agencies, or in connection with dynamic metamorphism.[1] The conditions under which dolomites originate are too diverse to permit the use of dolomitization as a criterion for degree of dynamic metamorphism in the associated formations.

FREDERIC H. LAHEE

GAS AT FARNHAM, UTAH

An unusual gas occurrence has recently been demonstrated by a drilling test of the Utah Oil Refining Company on what is known as the Farnham dome, about 15 miles east of Price, Utah. A sand at a depth of 3,100 feet was barely entered when gas began flowing and the volume soon became such that further drilling by ordinary methods was prevented. The two most noticeable features in connection with the gas were its strong odor of hydrogen sulphide and its refusal to burn or support combustion. Three days after the gas was encountered a sample was obtained and analyzed. This analysis is given below, with the analysis of a second sample taken two days later and investigated by the same method and analyst as the first.

ANALYSES OF NATURAL GAS FROM FARNHAM DOME, UTAH

	First Sample	Second Sample
	Per Cent	Per Cent
Hydrogen sulphide	0.20	0.20
Carbon dioxide	52.20	91.20
Carbon monoxide	2.21	.....
Oxygen	4.63	1.47
Hydrogen	0.66	.....
Nitrogen	38.98	6.51
Illuminants	0.32	0.62
	99.20	100.00

The sample first taken indicates a gas of most unusual constituency, chiefly with respect to the carbon monoxide content, although the nitrogen percentage is likewise exceptionally high considering the content of carbon dioxide. The high nitrogen, together with the apparent fact that

[1] Grabau, A., *Principles of Stratigraphy*, pp. 761, 762; Clarke, F. W., "Data of Geochemistry," *U. S. Geol. Survey Bulletin 695*, pp. 563–69.

the specific gravity of the gas as actually determined (1.195) is lighter than it should be by percentage computation gave some suggestion that helium was present. However, no test was made for that element, and the later analysis practically gives assurance of its absence subsequent to the earliest period of flow.

Up to date it has been found impossible to control the gas flow, for when a control head was fixed and gate valve shut the pressure built up and blew out the packing and clamps between two casing strings. The high rock pressure shown both by the fact that the well has been drilling itself in, with rocks of considerable size being thrown up to and beyond the crown block, and also by the low temperatures shown at the casing collar. A thermometer placed on the outside of the collar registered six below zero Fahrenheit.

Judging from rock fragments blown out of the hole the stratum in which the gas occurs is a fine-grained almost quartzitic sandstone. Presumably this sand is the uppermost of a succession in the lower half of the Moenkopi formation, considered as Lower Triassic in age. It is believed that the objective sand of the drilling test lies about 200 feet below the gas horizon.

The writer considers that the gas occurrence cited has no direct bearing on the question of petroleum possibilities in the basal portion of the Moenkopi formation, but that the gas had its origin from deep-seated emanations and ensuing chemical reactions. There is some evidence that the major structural feature of the region, the San Rafael swell, is the result of igneous intrusion at great depth, and that the minor structure on which the test well is located has a similar genetic history. The Farnham dome has a major fault on each flank which probably penetrate deep enough to have allowed gases from the assumed underlying intrusive to pass upward. Normally such gases should have been sulphurous, and coming in contact with either connate or meteoric water would have resulted in formation of sulphuric acid. This sulphuric acid reacting on the calcareous shales and sands in the Moenkopi formation would free carbonic acid gas which could have passed into the present reservoir stratum leaving precipitated gypsum along or near the fault lines. In this connection it may be of interest to note that a well drilled adjacent to a major fault line on another Utah structure disclosed thick masses of gypsum whose genesis was in all probability due to reactions similar to those suggested in connection with the gas occurrence at Farnham.

Because of the scientific and possible economic interest attaching to the Farnham gas discovery the writer would appreciate reference to occur-

rence of any similar gas known to members of the Association. Incombustible gases are not unknown in oil fields, but ordinarily analyses of them are not made, or at least are not usually given in the literature.

W. R. CALVERT

SALT LAKE CITY, UTAH
April 26, 1923

POSSIBLE EXPLANATION OF THE LARGE INITIAL PRODUCTION OF SOME WELLS OF THE HAYNESVILLE FIELD, LOUISIANA

In the Haynesville field, which produces from a single horizon commonly known as the Blossom sand, the initial yield of the wells ranged from a few hundred barrels per day by pumping up to perhaps 10,000 barrels by flowing. Wells yielding more than 3,000 barrels initial production were decidedly uncommon. The large and small wells were found to occur irregularly over practically the entire field, except perhaps the northern slope of the structure.

The writer found very interesting a study of the factors which determined the initial production of the wells. During the early history of the field little information was available, but as the number of completed wells increased, and the known field extended, it became clear that the initial production was independent of structural position, and largely independent also of the thickness of sand penetrated, date of completion relative to offset wells, and the manner in which the wells were finished.

Study of the cuttings from about thirty wells scattered over the western part of the field shows that the sand is characteristically of pebbly nature. The sand itself is composed chiefly of well-rounded quartz grains which are rather coarse and but slightly cemented. The pebbles consist chiefly of rounded hard, siliceous rocks. Chert, jasper, quartzite, quartz, and perhaps igneous rocks have been observed. Softer material, such as sandstone and rounded fragments of coal, are also present. In size the pebbles range up to two inches or more.

One of the largest and most spectacular wells of the field had to be shut in while the flow lines were cleaned of pebbles, sand, etc. At an offset well about two gallons of pebbles were obtained from the liner when this was removed. These instances are suggestive of the part that gravel beds may have in determining the capacity of the wells. It is believed that the chief factors influencing the rate of flow are: (1) size of the pores, and (2) the degree of porosity. In beds of gravel, composed only of such material as above described, the size of the pores might well range up to an inch or more, in greatest dimension; whereas in the

sand the size of the pores would probably be but one or two hundredths of an inch. Also, in the gravel the degree of porosity would be greater than in the sand. Thus, if gravel layers exist, and the pebbles composing them are not imbedded in sand, or if they are imbedded in sand, but the sand is uncemented and readily washed out, a rapid flow is to be expected, when these layers are reached.

The presence of pebbles in the cuttings from the sand gives no hint as to the probable rate at which a well will flow for as before stated they are characteristic of the sand over a widespread area. However, it is probable that in some parts of the field there are pebbles concentrated into layers or long lenticular masses by strong wave action, and that while these concentrations of coarse material were taking place the wave action was so vigorous as to carry the sands to quieter water. It is not unreasonable to assume that in part these pebble layers remained more or less open and free from sand, which if present would reduce the size of the pores, and the degree of porosity. When such a layer in an oil sand is penetrated by the drill a well of very large initial production, and a long life, is to be expected. The size of the pores permit rapid flow and the area tributary to the well may be much more extensive than where the bottom of the well is in sand of the ordinary sort.

M. ALBERTSON

SHREVEPORT, LOUISIANA
March, 1923

COMPOSITION OF OIL SHALES

Microscopic examination of oil-shales from all parts of the world, made at the oil shale laboratory of the Bureau of Mines, Boulder, Colorado, indicates that they are composed of:

1. Minute carbonized or partly carbonized fragments of plants, often showing cellular structure, small spores, pollen and the like.
2. Yellow or reddish-yellow, more or less spherical bodies, regarded as algae, spores, or globules of oil.
3. Irregular streaks of reddish-yellow, dark-brown, or opaque material.
4. Shells of small crustaceans, and parts of the skeletons and scales of fish.
5. Mineral matter, such as sand grains and pyrite crystals.

There is little evidence to indicate that animal life had much to do with the formation of the oil-yielding material of shales, and much evi-

dence to the contrary. Possibly the animal remains are the source of much of the nitrogen and sulphur.

In general, the following opinion prevails: That the yellowish globules and yellowish or brown, often nearly black, streaks in the shales, are the sources of oil when the shales are distilled, and that they are probably of vegetable origin, or are petroleum as such or in some altered form. The fact that little real oil can be extracted from shales by ordinary solvents of petroleum seems to preclude the idea that the globules are petroleum as such.

BUREAU OF MINES

THE HOCKLEY SALT DOME

The Hockley salt dome is situated about four and one-half miles due south of the station of Hockley, elevation 220 feet, on the Southern Pacific in the northwestern corner of Harris County, Texas. This salt dome is accessible by wagon road from Hockley to Warren's ranch.

The Hockley dome is on the southern edge of a topographic terrace, composed of Lissie gravels and sand, the general strike of which here is N. 50° E. The terrace has a general elevation of 200 feet above mean sea level, and its height is approximately 40 feet, the width of the terrace being about two miles. On the plain immediately to the southeast the general gradient is far less, approximately 35 feet in 11 miles. In the area of the dome the topography shows a slight re-entrance of the edge of the terrace to the northwest over the immediate salt core, this feature resulting from the growth of the salt core below. It is typical of salt dome topography where domes exist under similar geological conditions.

The cap rock and salt core areas indicated on the accompanying sketch (Fig. 1) have been approximately outlined by past drilling operations, more than 20 wells having been drilled on or about the uplift without encountering petroleum in commercial quantities. The surface area underlain by the cap rock is approximately one square mile while that of the salt core is about two and one-half square miles. The general depth of the cap rock below the surface is about 100 feet, and it is 1,000 to 1,100 feet to the salt core. Toward the side of the salt core, the depth to the rock salt increases very rapidly with short horizontal distances. The cap rock has been found to have an average thickness of 900 to 1,000 feet, and cuttings indicate that it is composed principally of secondary limestone, sand, limy sands, sandy limes, limy shales, sandy shales, gypsum, anhydrite, calcite, and a few small lenses of native sulphur with scattered nodules of iron pyrites. Portions of the cap rock are sufficiently

hard and dense to permit the use of cable tools in drilling. The strata are frequently very pervious and take up all the water and mud that a mogul rotary pump can feed to the formations when the rotary drilling system is used. Specimens of the rock salt encountered show some

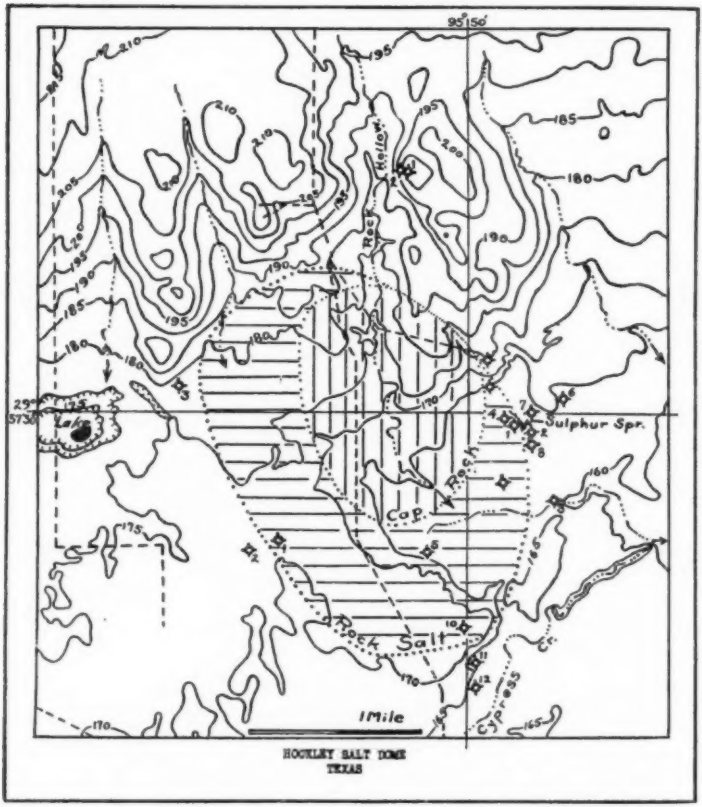


FIG. 1

anhydrite in the upper parts of the deposit. As yet no borings have penetrated the salt mass so as to determine its thickness.

An active spring discharging sulphur water and some H_2S gas is encountered near the eastern edge of the salt core. Any silver article

immersed in the fluid is quickly colored black with a deposit of silver sulphide. Sulphur springs are very frequently associated with areas known to be underlain by gypsum and rock-salt cores developed in relatively recent geologic times.

Of all the wells drilled on or about this uplift, only a few have given indications of petroleum or natural gas, and none produced in commercial quantities.

LEWIS C. CHAPMAN

REVIEWS AND NEW PUBLICATIONS

Field Geology (Second Edition). By FREDERIC H. LAHEE. New York: McGraw-Hill Book Co., Inc., 1923.

Field Geology is a clear, concise, and thoroughly practical volume of value to any geologist, whether beginner or of long experience. This is stated emphatically at the outset, because the criticisms made here are to be understood not as attempts to belittle the book, but as suggestions for making even better a future new edition.

A general impression of the book is that its chief strength and its chief weakness spring from the same source. The author has planned a volume that will serve "both for a textbook and for a pocket manual"; this is a difficult task which on the whole has been admirably met. More extensive treatment of general geology than is customary in handbooks has crowded out descriptions of some field methods and technique that would be of value; limitation to the size of a pocket manual has perhaps made some of the general geology rather sketchy for young students. On the other hand, unlike usual textbooks, it offers to the beginner actual methods of attacking problems—in fact, ready-made "experience"; for the more mature geologist it provides in easily carried form a reference to the many details of geology and technique that so often slip from the memory.

Much of the new material in the revised volume bears the trade-mark of "oil geology." Among the additions are sections on porosity, the compacting of sediments, lensing and other lateral variations, causes of tilting and folding, and the significance of the fixed carbon ratio of coal. An appendix on geologic mapping has been properly transferred to the chapters on geologic surveying, which have been expanded also by many new sections. In its second edition the book consists of twelve chapters dealing with "the recognition and interpretation of geologic structures and topographic forms," six chapters on methods of geologic surveying and of office work on the field data, an appendix containing several mathematical tables, a bibliography, and an excellent index.

A noteworthy feature is the inclusion of many tables or keys for the interpretation of observed facts. These bring side by side phenomena which resemble each other, and point out the criteria which must be sought for to differentiate the phenomena. The student should find such keys of greatest value if he will use them not as rule-of-thumb methods, but as a suggestion of how to develop habits of careful observation and deduction along orderly lines by making and testing out hypotheses.

A few suggestions and criticisms of minor points are as follows: In the key on page 11, it is stated that "the exposure has a massive appearance, its con-

stituents being neither grouped in layers nor oriented in parallel position. If (B) the rock is as coarse as a medium sandstone or coarser, being of relatively uniform grain, and consisting very largely of (2) grains of quartz, it is quartzite." More probably the rock described would be a massive quartzose sandstone. This key is somewhat inadequate in other respects, too little consideration being given to igneous rocks.

In the key on page 17 is the statement: "If (B) the rock is sedimentary, being (2) sand, sandstone, gravel, conglomerate, volcanic ash, or any other relatively coarse fragmental material, and has its bedding inclined more steeply than 35° to the horizontal, it has probably been tilted from its original position." In other parts of the book the author explains how high dips are sometimes formed in deposition; however, the statement here is misleading, as the inexperienced student might naturally infer that if the beds dip less steeply than 35° they have probably not been tilted. Even if such an inference is not drawn, the statement overweights the importance of depositional as compared to structural dips.

On page 372 the author mentions that the Brunton compass can be adjusted for true bearings, but does not note that the Gurley compass can be similarly adjusted.

In describing the cutting and mounting of maps on cloth (p. 414) it would help the beginner if he were advised to separate the sections a little in mounting, for greater ease of folding.

Plane table mapping is said (pp. 460, 462) to require two or more men—a statement which should refer only to stadia traverses or side-shots. Many geologists do all their mapping single-handed by triangulation, carrying elevations to and from monuments; the use of a rod in triangulation, described on page 470, is unnecessary.

To the outline of the common practice in stadia traverses (bottom of p. 456) should be added the statement that at instrument stations the plane table is oriented by means of the alidade compass (checked where possible by sights at known points).

Geologic surveying methods are well described at considerable length in two chapters. The value of these chapters would be made even greater by expansion or addition of several topics. In the present edition there is no mention of Bessel's method for solving the three-point problem (the most useful method, though apparently little known); no description of the care and adjustments of the alidade; no details of the use of the Beaman arc or the Stebinger drum and preparation of Stebinger tables; no method for taking "over-the-rod" shots; and no rule for applying curvature and refraction corrections, which must constantly be used in triangulation. These important topics could be included by sacrificing some of the lengthy and much less valuable statements on the use of the barometer and the preparation of block diagrams.

The illustrations are pleasing and adequate; type is large and clear. The only typographical errors noted are: Page 371, next to bottom line, A C should

be A E. ; Page 373, first two lines are reversed. Appendix, page 599, eleventh line from bottom, 30 ft. should be 30′ [minutes].

JULIAN D. SEARS

Algae Believed to Be Archean. By JOHN W. GRUNER. *Journal of Geology*, Vol. XXXI (1923), No. 2, pp. 146–49.

This paper describes briefly and discusses the occurrence of blue-green algae found in pebbles in the Okishge conglomerate, the lowest formation of Huronian age north of Lake Superior. The pebbles almost certainly come from the underlying Archean. This discovery is one more addition to the accumulating evidence that indicates that the reason oil is absent from the oldest sediments is not because there was no mother substance, but rather because of geochemical processes which have destroyed such petroleum as originally may have been present. If this is true it is possible that under exceptionally favorable conditions oil will be found in Cambrian or even pre-Cambrian beds.

K. C. HEALD

Bibliography of Petroleum and Allied Substances for 1919–1920. By E. H. BURROUGHS. Bureau of Mines Bulletin 216.

This is the fifth in the series of petroleum bibliographies published by the Bureau. More than two hundred American and foreign journals and numerous Federal and State governmental reports have been utilized in the preparation of the bibliography. References are given to papers on the geology and origin of petroleum; its geological distribution; development and production; transportation; storage and distribution; properties and their determinations; refining and refineries; utilization of petroleum and its products; regulations and legislation regarding petroleum; etc.

R. C. MOORE

Oil Shales of the Maritime Provinces, Canada

The Geological Survey of Canada issued during 1922, Memoir 129, *Geology of the Moncton Map Area*, by W. J. WRIGHT. The famous albertite vein is 15 miles south of Moncton, New Brunswick, and the Stony Creek gas field is 9 miles south of Moncton. The Memoir does not describe in detail the gas field, now nearly exhausted, but gives detailed information regarding oil shales at Albert Mines, Rosevale (Baltimore), near the Mines; New Glasgow and Antigonish, Nova Scotia; and Cape Breton Island. The Stony Creek gas is now thought to come from a terrace and not from the crest of an anticline, but the subsurface geology is complicated by a buried hill, the unconformity coming above the gas-bearing Albert series.

SIDNEY POWERS

Occurrence of Petroleum in Mackenzie River Region, Canada

All available information regarding the possibility of oil in the Mackenzie River region, including Fort Norman, has been published by the Geological Survey of Canada in the *Summary Report*, 1921, Part B, 1922. The papers by A. E. CAMERON, E. J. WHITTAKER, M. Y. WILLIAMS, G. S. HUME, and D. B. DOWLING occupy 90 pages. Two large maps show the geology. Mr. Dowling states that the discovery well produced from shale and that the production declined during the summer of 1921 to a few barrels per day. From other sources it has been learned that this well was deepened last summer and produced about 70 barrels a day. The test across the river and down the dip reached a depth of 1,500 feet, but has not yet found the same oil sand. A test of the Fort Norman Oil Co., 8 miles north of the Imperial well, found gas at 1,525 feet, and was shut down.

SIDNEY POWERS

The World Race for Oil. Literary Digest, January 20, 1923, p. 15.

A comprehensive and very interesting review, discussing the international political and economic aspects of the oil situation, appears in this number of the *Digest*. For those who appreciate how closely oil enters into various world problems the article has special interest.

J. H. HANCE

The Roumanian Petroleum Industry during the First Quarter of 1922. By ANDRE SURNY DE BONNIER. Engineering and Mining Journal-Press, August 19, 1922, p. 332.

The author calls attention to the increased output as compared with that of 1921, in spite of the power shortage and transportation difficulties. Compared with the corresponding quarters of 1921 the increase was about one-sixth. Political and economic problems are acute, and interference and monopolistic conduct on the part of the government have destroyed most of the incentive of producing companies.

J. H. HANCE

The Possibilities of Oil in Western Dewey County, South Dakota. By FREEMAN WARD and ROY A. WILSON. Circular 9, South Dakota Geological and Natural History Survey, September, 1922. Pp. 10, figs. 4.

This brief pamphlet summarizes the results of field work done in a locality considered by the authors to represent one of the most likely areas in the state. The rocks which outcrop are the Pierre, Fox Hills, and Lance, all of Cretaceous age. Because of variable characteristics certain key beds were selected, and outcrops of these were carefully mapped with plane table and telescopic alidade. The accompanying map shows a structure with three closed 25-foot contours, the lower one including an area of about 15 square miles.

A well of about 3,000 feet might be necessary to test the oil prospects at this place. Deep well records involve localities at least 45 miles distant. "The thickness, number and productivity of the oil sands diminish from central to eastern Wyoming and Montana. Many of these sands are completely absent in eastern and central South Dakota and no oil has been found in the thousands of artesian wells drilled in that part of the state. Western South Dakota is intermediate in position between the entire absence of production in eastern South Dakota and the moderate production of eastern Wyoming."

J. H. HANCE

New Oil Pool at Tidioute and Gas Pools near Corry and Meadville, Pennsylvania. By M. E. JOHNSON. Bull. 51, Pennsylvania Bur. Top. Geol. Survey.

New discoveries of oil and gas in northwestern Pennsylvania were made early in June, 1922. However, oil production was first developed at Tidioute in 1860 from the Second and Third Venango oil sands. After flooding, the pool was unwatered in 1904 and good production was again obtained. This soon declined, but the field has continued to yield rich gas. The early history of the pool indicated little hope of production below 1,500 feet, although several wells were continued below that depth.

About four miles south of Tidioute an oil sand, locally termed the Queen sand, has been found 700 feet below the Third sand, and drilling in 1922 proved this lower sand productive at Tidioute. Wells were brought in with an initial daily yield up to 800 barrels, and have flowed naturally by heads. The oil is a light-colored greenish yellow, and has a gravity of 47.7° Be. The new productive area is of small extent, and appears to be due to a terrace on the widespread southward-dipping monocline of northwestern Pennsylvania and New York.

Late in 1921 a small gas sand was brought in near Corry, Erie County. The wells are 800 feet deep, and develop the gas from a stray sand considered near the horizon of the Glade sand in the Devonian.

Another gas pool was brought in during June, 1922, at Meadville, Crawford County. The first well showed an initial rock pressure of 150 pounds, and developed a flow of 900,000 cubic feet of gas at a depth of 512 feet. The production comes from a Devonian sand, and is thought to be due to a local structural feature.

J. H. HANCE

Oil Fields Rejuvenated. By ROBERT B. BOSSLER. Pennsylvania Bureau of Topographic and Geological Survey. Bulletin 56, September 1, 1922.

This bulletin discusses several methods of rejuvenating oil wells, classifying them in two groups; those applied to pools or leases and those applied to single wells. The methods applicable to pools or leases include restoration of pressure either by water-flooding or by compressed air, and dewatering. Methods applied to single wells are: cleaning, and developing upper sands.

Particular emphasis is laid on the methods of water-flooding employed in the Bradford pool, in McKean County, Pennsylvania, and Cattaraugus County, New York. The Bradford sand is described as a very uniform gray and white sand of about the coarseness of ordinary beach sand of the Jersey coast, with an average thickness of about 45 feet. The average porosity is not given. Rejuvenation of this sand is accomplished by water flooding which was initiated deliberately about 30 years ago, although probable accidental flooding had taken place before that time. Since the method was adopted about 25 per cent of the entire pool has been flooded, leaving 75 per cent yet to be invaded by water. By this method of recovery output has been increased from 100 to several thousand per cent. Wells without natural production have been made to yield thousands of barrels of oil, and some producing wells have produced many times more than the quantity delivered before flooding.

Flooding progresses most rapidly through the oil sand of wells that produced freely, and moves slowly where the wells were least prolific, the rate of advance of flood water apparently being controlled by hydrostatic head. In one locality cited the water has not advanced 175 feet in three years; in another it advanced 235 feet in a year.

Various modifications of method are used in admitting flood water to the oil sand but all of them involve drilling of new wells rather than utilization of old ones. Water is obtained from a water-bearing sand above the oil sand and intermediate sands are protected from inundation by water. The results obtained by flooding have raised the prices of unflooded land for leases, which some years ago were sold at the value of the casing and tubing in the wells, to from $900 to $1,350 per acre and in some cases to as much as $15,000 per barrel day.

Assuming average conditions, the probable recovery by normal yield and by flooding combined is about 10,000 barrels per acre. A rough computation indicates that the original content was 37,000 barrels per acre, so, plainly, even flooding fails to remove as much as half the oil it originally contained. Mr. Bossler expresses a belief that the Bradford sand could possibly be unwatered successfully and much oil recovered after the area is completely flooded.

The Smith-Dunn process which restores pressure by means of compressed air was once used successfully in Bradford, but was discontinued because the natural gas was spoiled by adulteration with compressed air. Few precise data are available, but in most cases the method apparently has been successful with respect to the oil produced. A percentage tabulation shows that increase in production on five properties in Ohio by the Smith-Dunn process ranged from 14 to 95 per cent.

Unwatering has been used with conspicuous success in the Tidioute and the Petroleum Center-Pioneer fields of Pennsylvania. Production by unwatering in the Tidioute field began in 1904, when, after pumping water for six months, one operator began to produce an increasing volume of oil. In the Pioneer field an attempt to rejuvenate oil wells was made in 1917. By pump-

ing continuously the water was exhausted and some gas obtained. At Tidioute vacuum is now applied universally, so that new wells drilled show "back suction."

Cleaning methods applied to individual wells are listed as: (1) Squib shooting, (2) Treatment with gasoline or kerosene, (3) Treatment with chemicals, acids, or alkalis, (4) Use of heat producing chemicals, (5) Treatment with hot salt water, (6) Treatment with steam, and (7) Use of electrical heating devices. The author states that probably the most promising method of cleaning is by electrical heating, and he mentions some very encouraging results obtained by this method.

Discussion of the development of the upper sands is very brief, merely calling attention to the fact that in a number of fields it was known that upper sands were oil-bearing, but they were passed through in order to obtain a more prolific flow from sands below. The upper sands are now being exploited, in many instances utilizing the holes drilled to the lower sands.

The paper concludes with an estimate of reserves. Those for Pennsylvania are given as 487,000,000 barrels. Presumably this estimate is for January 1, 1922. The method used in arriving at this figure is described briefly. In the final paragraph the author calls attention to the fact that no mention is made in the paper of the use of shafts and galleries, and voices an opinion that enormous quantities of petroleum may possibly be obtained in this way.

K. C. HEALD

The Fauna of the So-called Dakota Formation of North-Central Colorado and Its Equivalent in Southeastern Wyoming. By JOHN B. REESIDE, JR., United States Geological Survey Prof. Paper 131–H, April 23, 1923. Pp. 6, pls. 6.

In this paper the previous work on the paleontology of the strata dealt with is briefly mentioned, and new evidence obtained both from the old collections and from recently gathered collections is presented. It is stated that "a correlation based on the fauna must be a correlation with the Washita rather than with the Benton." The fauna on which this conclusion is based is both described and pictured.

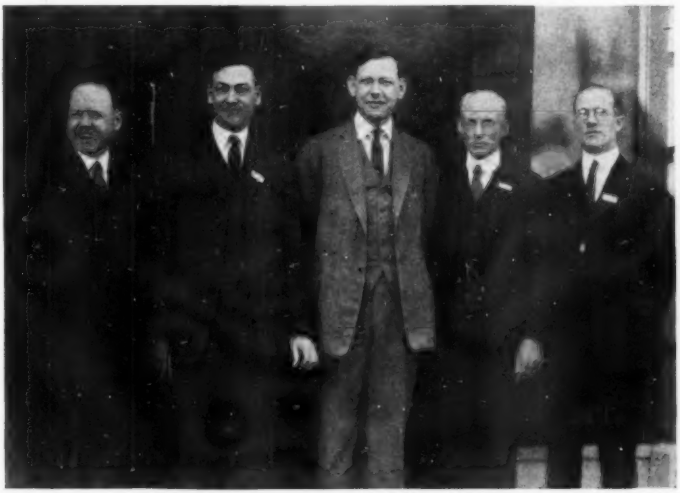
The publication is of interest to oil geologists who have to do with the Rocky Mountain fields, since it deals with strata that yield large amounts of oil in certain fields, and that may be the source of oil found in a number of localities. It is noteworthy that the fauna in northern Colorado and southeastern Wyoming, where the beds contain oil, is remarkably limited both in the variety of forms and in the numbers of individuals present, contrasting with a much more abundant fauna in areas where the beds apparently are barren of oil. Whether or not this has any connection with the occurrence of oil depends on the correctness of the assumption that at least some of the oil found in these beds originated in them.

K. C. HEALD

THE ASSOCIATION ROUND TABLE

PROCEEDINGS OF THE ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, SHREVEPORT, LOUISIANA, MARCH 22, 23, 24, 1923

As the editor, Mr. Moore, has given a general report of the meeting in Volume VII, Number 2, of the *Bulletin*, together with a copy of the program and a list of the members present, only the transactions of the business meetings remain to be reported.



OFFICERS OF THE ASSOCIATION FOR 1922–23

Left to right, Max W. Ball, *Vice-President;* George C. Matson, *Retiring President;* W. E. Wrather, *President;* C. E. Decker, *Secretary-Treasurer,* and Raymond C. Moore, *Editor.* Shreveport convention, March, 1922.

At the two business meetings of the Association Friday and Saturday mornings, Mr. W. E. Wrather presided. W. E. Pratt was called to the chair while the president reported as to the success of the Denver meeting, encouraged members in general to supply more material for the *Bulletin*, and expressed regret that the code of ethics had not been placed in final satisfactory form.

Report of the President[1]

It seems proper that the president should review briefly the activities of the Association at the close of the year and pass on to his successor a few suggestions, based on experience, relative to problems which demand the continuing attention both of the executive committee and the membership at large. This consideration prompts the following remarks.

Foremost among Association activities of the past year was the eminently successful meeting held in Denver during October. Due to the hearty cooperation of the Rocky Mountain geologists, the venture of a mid-year meeting, which had previously been quite generally viewed with misgiving, proved an unqualified success. For sustained interest in the technical sessions and for the superior quality of the papers presented, the Denver meeting was one of the most successful ever held by the Association. The organization has been most definitely benefited by it. A mass of valuable geologic data was provided for future publication in the *Bulletin*, much of which would without doubt never have been presented except for the meeting; and a large number of geologists who theretofore had not been particularly interested in the activities of the Association, are now enlisted among its enthusiastic supporters.

The problem of policy as to future mid-year meetings is the natural outgrowth of the Denver meeting. Such gatherings held at a distance from the headquarters of the majority of the members, can scarcely be expected to attract a large attendance from outside a given local area. It has been sufficiently demonstrated, however, that a meeting can be a pronounced success without a large outside attendance. The attitude of the Association should be that mid-year meetings are primarily for the benefit of the membership within a local area. To hold a successful local meeting, it is necessary that a nucleus of members, willing to assume the responsibility for the local management, should be located at a point easily accessible to an area in which a large number of geologists are working. This factor alone definitely limits meeting places outside the Mid-Continent district to perhaps not more than half a dozen cities, as long as the geographic confines of the oil industry are drawn as at present.

It does not seem advisable that the Association should now be committed to an established policy of holding a mid-year meeting each year. A growing rebellion against the multiplicity of scientific meetings is noticeable in recent years. The demands both in time and money of attendance at various scientific gatherings are beyond the means of the average geologist engaged in economic work. But mid-year meetings can be of such decided advantage both to the Association and to its local contingents of members that they should be sanctioned and encouraged, perhaps at irregular intervals, where, in the opinion of the executive committee, the local demand is sufficiently enthusiastic and well grounded.

[1] Read before the Shreveport meeting of the Association, March, 1923.

It is self-evident that the most valuable and lasting feature of the functioning of the Association is the accumulation of technical literature on the geology of petroleum which is year by year put on permanent record in the *Bulletin*. Therefore the welfare of the *Bulletin* should always be the most important work of the officers. This fact has been recognized by the present executive committee. Much thought has been devoted to the subject to the end that the *Bulletin* should become such a pre-eminent leader in the province of petroleum geology that it would be indispensable to workers in that field. Gratifying success has been obtained in the past along these lines but much remains to be done. There seems to be abundant reason why petroleum geologists should aspire to publish the results of their investigations in the *Bulletin*. Without question it reaches the audience of the majority of readers who are interested in petroleum geology. There is the further consideration also that a concerted effort should be made to assemble the majority of the literature on this subject in one publication rather than allowing it to be scattered promiscuously through dozens of publications as has been the custom in the past. This last statement, however, should not be considered as antagonistic toward the several established geological journals in which papers on oil occasionally appear. Such journals are entitled to consideration and support and no effort should be countenanced which would be detrimental to their welfare.

Among the problems for the future connected with the *Bulletin* the following should be considered:

1. Papers should be contributed at intervals throughout the year, just as is done with other periodicals. At present the programs of meetings supply too large a proportion of the material at the disposal of the editor. Too often subjects are presented orally at meetings and the editor is obliged later to resort to correspondence to procure manuscript for publication. The burden should rest with the author to submit to the editor, without solicitation, a manuscript in suitable shape for use in the *Bulletin*.

2. Insufficient attention is paid to foreign geology. Many members of this Association are now engaged abroad and yet surprisingly little of the subject-matter in the *Bulletin* deals with foreign geology. No doubt, as the results of foreign investigations are released for publication, this shortcoming will ultimately be overcome; but there is undoubtedly far more material available for publication at the present time than finds its way to the *Bulletin*. A concerted effort should be made to locate such material and encourage its publication.

3. The *Bulletin* does not yet reach all those to whom it would be helpful. The executive committee has considered this feature and taken steps designed ultimately to correct it, as will no doubt be mentioned by the Secretary.

4. Too little use is made of the *Bulletin* as a medium for co-operative investigation. Geologists can and will aid each other in the development of individual problems if requests for particular information are published in the department of the *Bulletin* devoted to research. It is earnestly to be hoped

that members will avail themselves of the new department and help establish it as a permanent feature of the publication.

Other points might be enumerated but the foregoing will serve to indicate that the *Bulletin* can be made infinitely more serviceable as time goes on, provided every member of the Association will assume an individual responsibility to assist and carry the work forward.

It is highly desirable that a feeling of responsibility for the success of this Association shall be cultivated among the membership at large. Too much of the work of the Association is done by a limited number of willing workers. As long as this is true, the continued success of the organization is not secure. Among the younger members there is a large reserve of latent ability which needs only to be sought out, directed and developed. The executive committee should take the initiative in devising means for trying out and enlisting the talents of the younger men

Throughout the year considerable attention has been devoted to a consideration of a proposed code of ethics. A rather inconclusive vote was received in response to the preliminary ballot which was sent out early in the year; and lately there has been an expression in favor of only a brief statement of general principles. A somewhat detailed code of ethics would have been of great value to the executive committee during the past year, and this is likely to be the case in succeeding years. This committee no doubt appreciates more than do the individual members, the value of an accepted statement of those acts which constitute a breach of ethics. If a code can be framed which will be acceptable to the majority of the members it is highly desirable that it should be adopted by the Association.

W. E. WRATHER

The report of the president was approved, and he called for the report of Mr. Decker, secretary-treasurer.

REPORT OF THE SECRETARY

March 20, 1923

Vote on constitutional changes following meeting of March, 1922:

1. To increase requirement for associate members from twenty to thirty hours of geology:
   For increase, 333; against increase, 31
2. To establish honorary membership:
   For, 317; against, 44
3. To empower editor to appoint associate editors:
   For, 342; against, 21

Full members at time of meeting	631
Necessary ¾ vote	473
Total vote cast	366
Number lacking decisive vote	107

Accordingly all three of the propositions failed.

Membership of the Association:

Number of members, March 15, 1919	210	
Number of members, March 18, 1920	392	
Number of members, March 15, 1921	621	
Number of members, March 8, 1922	767	
Number active members, March 20, 1923		712
Number associate members, March 20, 1923		189
Total number of members March 20, 1923		901
Applicants elected, dues still unpaid	27	
Applicants approved for publication	57	
Recent applications	38	
Total number of applications		122
Number of members withdrawn		6
Number of members dropped		2
Number of members died		3
Active members in arrears, 1921 dues	11	
Associate members in arrears, 1921 dues	6	
Total members in arrears, 1921 dues		17
Active members in arrears, 1922 dues	29	
Associate members in arrears, 1922 dues	12	
Total members in arrears, 1922 dues		41
Active members in arrears, 1923 dues	199	
Associate members in arrears, 1923 dues	78	
Total members in arrears, 1923 dues		277

Respectfully submitted,

CHARLES E. DECKER, *Secretary*

REPORT OF THE TREASURER

March 20, 1923

Cash in bank, March 11, 1922:

In open account	$ 1,733.54	
In savings account	5,597.41	$ 7,330.95

Receipts from dues:

Associate dues	$ 1,194.00	
Full membership dues	7,974.13	$ 9,168.13

Receipts from sale of "Bulletins":

Vol. I (1917)	$ 123.45	
Vol. II (1918)	94.30	
Vol. III (1919)	129.60	
Vol. IV (1920)	228.15	
Vol. V (1921)	441.17	
Vol. VI (1922)	591.70	
Vol. VII (1923)	628.59	
Vol. VIII (1924)	54.50	
Bound copies of Vol. VII	18.00	
Postage received	1.30	$ 2,310.76

Miscellaneous receipts:

Advertising	$ 964.11	
Interest	241.26	
Separates	79.25	
Rocky Mountain Geological Society	45.00	
Refund from Capper Engraving Co	39.65	
Exchange	0.25	$ 1,369.52
Unclassified receipts		80.67
Grand total		$20,260.03

Disbursements:

Cost of *Bulletin* for year:		
Printing	$ 4,278.84	
Engraving	346.02	
Postage	133.11	
Editor's salary	600.00	
Assistants' salaries	239.31	
Advertising expenses	111.16	
Miscellaneous	46.06	
		$ 5,754.50

Expense of meetings:

Oklahoma City meeting	$ 190.00	
Denver meeting	85.43	
Shreveport meeting to date	40.75	
		$ 316.18

Expenses of general office:

Secretary-treasurer's salary	$ 600.00	
Stenographic work	433.70	
Printing	317.21	
Postage	194.79	
Returned checks	88.50	
Cost of separates	36.93	
Supplies	38.38	
Drayage, express, freight	14.14	
Refunds	6.00	
Miscellaneous	16.58	$ 1,736.23
Total expense		$ 7,806.91

Balance in open account	$ 5,895.83	
Balance in savings account	6,638.67	
	$12,534.50	
Outstanding checks	81.38	
Bank balance		$12,453.12
Total expenditures plus bank balance		$20,260.03

Summary of resources for the last five years:

1919	$ 83.54
1920	926.89
1921	3,582.76
1922	7,291.15
1923	12,453.12

Respectfully submitted,

CHARLES E. DECKER, *Treasurer*

Having examined the accounts, receipts, checks, and stubs of C. E. Decker, treasurer, in detail, I pronounce this statement of the condition of the finances of the American Association of Petroleum Geologists correct.

(Signed) A. E. THOMAS, *Accountant*

The reports of the secretary-treasurer were adopted with expressions of appreciation.

REPORT OF THE EDITOR

The development of the *Bulletin* during the past year hinges on excellent team-work of the entire Executive Committee. Therefore, the points already covered in connection with the policies and actual work which has been done by the Committee, should be mentioned here.

The relation of the *Bulletin* to the holding of a midyear meeting has been shown by the considerable number of papers which have resulted from the Denver meeting.

In the first number of Volume VII you have noted some changes in the appearance of the *Bulletin*. In arranging for the publication by the University of Chicago Press, our *Bulletin* is placed in the hands of a staff long trained in getting out scientific literature. Those of you who are familiar with printing will appreciate in various details improvements which are to be included from now on.

The addition of advertising is an innovation of the past year, and appreciation of the work done by the advertising manager, Mr. J. Elmer Thomas,

should be cordially expressed. The work of his office is reported in the following statement:

Miscellaneous expenses	$ 28.57
Total advertising contracted	1,929.00
Total advertising appeared in *Bulletin*	1,198.00
Total advertising collected	1,014.00
Of this latter sum checks not yet paid to the treasurer	83.32

Arrangements have been made on behalf of members of the Association, under which each member who so desires will not only receive as issued each number of the *Bulletin*, but in addition a library buckram-bound copy of the entire volume. This bound copy may be secured by ordering in advance from the secretary. The cost is $2.00.

Acknowledgement is made to the associate editors for the very efficient help which is rendered.

Mr. J. R. Pemberton has submitted recently an index of the first six volumes of the *Bulletin*. This will be printed as a separate pamphlet, and sent to each member of the Association. Mr. Pemberton's contribution to the *Bulletin* deserves our cordial thanks.

Respectfully submitted,

RAYMOND C. MOORE, *Editor*

The report of the editor was adopted with expressions of appreciation.

REPORT OF COMMITTEE ON CONSTITUTION

The Committee on the Constitution found that no change in the Constitution is necessary in order to change the method of electing officers. Article IV, Section 2, leaves full latitude for election by the "Association at large" by any method.

The Committee suggested that the president might hold a trial election next year, under some new method, to determine its effect in operation, before deciding whether to adopt the new method, or how best to modify it. If elections are again held by the present method the Committee recommended that they be held on the first day of the meeting.

The Committee on the Constitution recommended that Article VI of the Constitution (as printed in the *Bulletin*, Vol V, page 3) be amended as follows: On line 2 in place of the words "at least five members" write "at least twenty-five members." And on the last line of the same article, in place of the word "three-fourths," write "one-half."

CHESTER W. WASHBURNE, *Chairman*
WALLACE PRATT
JAMES H. GARDNER
F. G. CLAPP

Report of General Committee

The General Committee recommended that the Executive Committee decide whether or not the recommendations passed by the Constitution Committee referring to the election of officers be accepted, and further, that the Executive Committee also decide what further measures should be taken to improve the present methods of election of officers.

In regard to the changes recommended in Article VI of the Constitution, as printed in *Bulletin*, Volume V, page 3, the General Committee recommended that "they be passed by the majority of those voting, provided more than one-half of the members voted." The only change suggested here is "more than one-half," instead of "one-half" as proposed by the Constitution Committee.

This recommendation was adopted by motion.

The General Committee also recommended that the three amendments to the Constitution which were voted on during the past year and defeated be resubmitted.

New Business

The following recommendations were adopted on motion:

1. The recommendation to the Executive Committee that the salary of the secretary-treasurer be increased a reasonable amount and that the traveling expenses of his position be paid.

2. The recommendation to the Executive Committee that bibliographies of all publications pertaining to our work be published, as they come out, in every *Bulletin*.

3. The recommendation that the Legislative Committee give immediate attention to ways and means of supporting the Temple Bill (the completion of the topographical map of the United States) and that they co-operate with the Federated Engineering societies in the work which they are at present doing along this line.

4. That the president of the Association appoint a committee to be responsible in so far as possible, for abstracts of literature dealing with oil geology; this committee to have a representative if feasible, on every local geological society that has a number of oil geologists in its membership.

5. That attention be brought to the members of the entire Association of the rather small number of associate members that are coming into the Association, and that some discussion be allowed regarding the best methods, if desirable, of securing more associate members.

6. That a vote of thanks be extended to Mr. J. R. Pemberton for his splendid work in making a bibliography of the first six volumes of the *Bulletin*.

7. That we accept the invitation extended by the members from California to hold a fall meeting in Los Angeles.

An invitation was presented by members from Ardmore, Oklahoma, to hold the next annual meeting there. This invitation was referred to the Executive Committee.

The following recommendation was deferred for further consideration: a recommendation to the Constitutional Committee, through the Executive Committee, that provision be made in the Constitution for the election annually of regional vice-presidents.

The following recommendation was laid on the table: a recommendation to the Executive Committee that the annual meetings of the Association be held in cities of not less than 50,000 population.

WALLACE PRATT, *Chairman*	F. H. LAHEE
R. S. MCFARLAND, *Secretary*	E. G. GAYLORD
C. W. WASHBURN	MAX W. BALL
M. E. WILSON	SIDNEY POWERS
JOHN R. SUMAN	C. H. WEGEMANN
L. J. PEPPERBERG	BEN K. STROUD
K. C. HEALD	E. B. HOPKINS
IRVING PERRINE	S. H. GESTER
R. S. MCFARLAND	ARTHUR KNAPP
FRITZ AURIN	F. W. DEWOLF

In electing a president for the ensuing year, James H. Gardner and Max W. Ball were nominated, and the latter was elected. Frank W. DeWolf was the only nominee for the office of vice-president, and Charles E. Decker and Raymond C. Moore were re-elected secretary-treasurer and editor, respectively. These four with Mr. W. E. Wrather, the retiring president, constitute the Executive Committee.

REPORT OF THE RESOLUTIONS COMMITTEE

During the present meeting of the American Association of Petroleum Geologists, the mayor, Chamber of Commerce, people, and press of Shreveport, and the management of the Youree Hotel, contributed largely and freely to the success of the program and entertainment of those attending, and the Association desires heartily to extend its appreciation.

We feel that especial thanks are due to the International Derrick and Equipment Company, Mr. A. C. Glassell, Mr. J. Edgar Pew, Miss Mary Gillespie, and all members of the local committees, for the assistance rendered and the amount of energy and effort so cheerfully given by them to make the Shreveport meeting one of the most successful and pleasant ever held.

R. S. MCFARLAND
DAVID DONOGHUE
C. M. RATH

REPORT OF THE LADIES' RESOLUTIONS COMMITTEE

WHEREAS, The Eighth Annual Meeting of the American Association of Petroleum Geologists has been characterized by the congeniality and good-fellowship engendered, and

WHEREAS, The program of entertainment especially provided for the ladies has been unusually elaborate and effective and particularly pleasing to the large number of ladies in attendance, and

WHEREAS, The ladies who have received these attentions are desirous of expressing their very great appreciation and their most sincere thanks to Mrs. C. M. Bennett, chairman, and other ladies of the Shreveport delegation, and also to the local committees in charge of this program,

Now, therefore, be it resolved, That the thanks of the entire Association is due the Shreveport delegation for the welcome accorded the visiting ladies, and that the secretary be instructed to send to the Shreveport press a copy of this resolution.

MRS. SIDNEY POWERS
MRS. WALLACE PRATT
Committee

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)

FOR FULL MEMBERSHIP

Harry Aid, Ranger, Texas
E. M. Closuit, David Donoghue, H. Abrahamson

Gustavus E. Anderson, Norman, Oklahoma
C. W. Shannon, Charles W. Honess, S. Weidman

Philip H. Bohart, Vera Cruz, Mexico
C. M. Crebbs, L. P. Garrett, C. W. Hamilton

Albert C. Boyle, Jr., Laramie, Wyoming
F. F. Hintze, F. M. VanTuyl, Max W. Ball

Marius R. Campbell, Washington, D.C.
David White, K. C. Heald, W. C. Mendenhall

Joseph M. Dawson, San Antonio, Texas
Paul L. Applin, Grady Kirby, Dilworth S. Hager

Florin W. Floyd, St. Louis, Missouri
R. S. McFarland, F. H. Lahee, W. C. Thompson

Arthur M. Hagan, Morgantown, West Virginia
W. C. Spooner, R. V. Hennen, Alfred Gray

Gerhard Henny, Ponca City, Oklahoma
E. L. Jones, Jr., W. Van Holst Pellekaan, T. K. Harnsberger

Maurice J. Hopkins, Casper, Wyoming
W. H. Geis, J. S. Irwin, E. L. Eastabrook

Dibrell P. Haynes, Chicago, Illinois
G. B. Morgan, Edward D. Lynton, M. J. Munn
John Whitney Lewis, Los Angeles, California
Stanley C. Herold, Edwin B. Hopkins, Bernard H. Lasky
George C. Martin, Washington, D.C.
David White, K. C. Heald, W. C. Mendenhall
Harold S. Cave, Houston, Texas
R. F. Baker, H. T. Kniker, F. C. Sealey
Charles E. Clowe, Ardmore, Oklahoma
F. H. Lahee, John G. Bartram, L. B. Benton
Ernst Ganz, The Hague, Netherlands
B. H. Van der Linden, W. C. Klein, F. A. A. Van Gogh
Peter S. Haury, Dallas, Texas
H. W. Bell, Leon J. Pepperberg, F. H. Lahee
Erwin H. MacDonald, Billings, Montana
C. H. Wegemann, C. Max Bauer, A. A. Hammer
Francis I. Martin, New York City
C. W. Hamilton, C. M. Crebbs, E. E. Boylan
Fred P. Shayes, Shreveport, Louisiana
Ben K. Stroud, W. C. Spooner, J. P. D. Hull
Frank M. Smith, El Dorado, Arkansas
H. W. Bell, Leon J. Pepperberg, F. W. Lahee
John W. Whitehurst, Shreveport, Louisiana
A. W. Duston, David Donoghue, R. S. McFarland
C. R. McCollom, Los Angeles, California
Ben K. Stroud, James M. Douglas, Max W. Ball
Millard F. Nesbit, Wichita Falls, Texas
D. W. Ohern, Edward W. Ames, Edgar Kraus
Sheridan A. Thompson, Houston, Texas
Alexander Deussen, John R. Suman, W. F. Bowman
Walter C. Toepelman, Boulder, Colorado
Angus McLeod, R. C. Moore, Irvine E. Stewart
J. P. Schumacher, Houston, Texas
F. B. Plummer, Wallace E. Pratt, John C. Suman
August L. Selig, Lawrence, Kansas
George A. Elledge, J. E. Brantly, Wallace E. Pratt
Charles R. Vorck, Washington, D.C.
John Cullen, L. S. Panyity, L. R. Van Burgh
Lloyd E. Wells, Dallas, Texas
J. W. Merritt, P. S. Justice, W. C. Spooner
Harold F. Crooks
W. P. Haynes, Ray P. Walters, F. M. Van Tuyl
Roy S. Rhoades
L. Trumbull, Colin C. Rae, Dean M. Stacy

FOR TRANSFER TO FULL MEMBERSHIP

Fred M. Bullard, Norman, Oklahoma
Chas. W. Honess, George D. Morgan, C. W. Shannon
Oliver C. Harper, Sweetwater, Texas
L. P. Garrett, David Donoghue, E. M. Closuit
Roy Holloman, Dallas, Texas
W. E. Wrather, David Donoghue, Wallace E. Pratt
Ambrose A. Langworthy, Tulsa, Oklahoma
George C. Matson, L. H. White, L. G. Keppler
George I. McFerron, Tulsa, Oklahoma
Robert H. Wood, Virgil O. Wood, W. B. Wilson
William W. Rubey, Washington, D.C.
K. C. Heald, Sidney Paige, David White
J. Boyd Best, Shreveport, Louisiana
E. G. Woodruff, J. Elmer Thomas, W. C. Spooner
Leslie S. Harlowe, Shreveport, Louisiana
J. P. D. Hull, M. E. Wilson, Clyde M. Bennett
William V. Hoyt, Tulsa, Oklahoma
Geo. C. Matson, Charles T. Kirk, W. B. Wilson
Gayle Scott, Fort Worth, Texas
W. M. Winton, J. A. Udden, E. H. Sellards
George Sawtelle, Houston, Texas
John R. Suman, David Donoghue, Wallace E. Pratt
Edmund B. Stiles, Dallas, Texas
J. A. Udden, F. H. Lahee, E. H. Sellards
George O. Suman, Jr., Oil Center, California
J. A. Taff, E. G. Gaylord, G. C. Gester

FOR ASSOCIATE MEMBERSHIP

Philip H. Austin, Pittsburgh, Pennsylvania
L. G. Huntly, Roswell H. Johnson, R. E. Somers
William D. Blackburn, Houston, Texas
Wallace E. Pratt, D'Arcy M. Cashin, H. J. McLellan
Bernerd W. Blanpied, Magnolia, Arkansas
E. W. Hummel, W. F. Absher, Claude F. Dally
William B. Berwald, Pittsburgh, Pennsylvania
Roswell H. Johnson, L. G. Huntly, R. E. Somers
John E. Burley, Lawrence, Kansas
R. S. Knappen, R. C. Moore, C. S. Corbett
Ronald J. Cullen, Tonkawa, Oklahoma
V. E. Monnett, Frank A. Edson, Oren F. Evans
Francis W. Dakin, Golden, Colorado
F. M. Van Tuyl, Harry L. Baldwin, Jr., R. A. Conkling

Paul A. Grant, Columbus, Montana
F. M. Van Tuyl, Harry L. Baldwin, Jr., Max W. Ball
George R. Hopkins, Dallas, Texas
Chas. H. Row, Wallace C. Thompson, F. H. Lahee
Henry L. Hummel, Okmulgee, Oklahoma
R. W. Clark, W. E. Bernard, O. L. Brace
Nate P. Isenberger, Salina, Kansas
R. S. Knappen, R. C. Moore, C. E. Decker
William H. Krecker, Jr., Pittsburgh, Pennsylvania
L. G. Huntly, Roswell H. Johnson, R. E. Somers
Charles B. McClintock, Pittsburgh, Pennsylvania
Roswell H. Johnson, R. E. Somers, L. G. Huntly
Harry W. Oborne, Bartlesville, Oklahoma
Max W. Ball, L. C. Snider, Chas. C. Hoffman
Ernest K. Parks, Stanford University, California
A. F. Morris, Eliot Blackwelder, R. D. Reed
Eugene P. Philbrick, Okmulgee, Oklahoma
R. W. Clark, W. E. Bernard, E. W. Hummel
Byron Rife, Independence, Kansas
Roy A. Burt, Henry A. Ley, Alex. W. McCoy
Parker A. Robertson, Tampico, Mexico
C. M. Crebbs, L. P. Garrett, C. W. Hamilton
Ira H. Stein, Cherokee, Oklahoma
Oren F. Evans, S. Weidman, V. E. Monnett
Leslie M. Wilshire, Lawrence, Kansas
R. C. Moore, C. S. Corbett, R. S. Knappen
Ira E. Dugan, Ponca City, Oklahoma
R. A. Conkling, Samuel J. Caudill, Glenn C. Clark
Roy D. Jones, Tulsa, Oklahoma
S. Weidman, V. E. Monnett, J. B. Umpleby
Rowland W. Laughlin, Tulsa, Oklahoma
James H. Gardner, R. S. McFarland, Alexander Deussen
William J. Nolte, Shreveport, Louisiana
G. B. Morgan, Edward D. Lynton, Robert S. Burg
Arthur Turman, Bakersfield, California
E. M. Butterworth, Carroll M. Wagner, E. D. Nolan
Joe W. West, Purcell, Oklahoma
J. B. Umpleby, V. E. Monnett, Fanny C. Edson
Charles E. Wuensch, Chicago, Illinois
Max W. Ball, Arthur Knapp, John L. Henning

OBITUARY

PHILIP CHARTERIS ANSTRUTHER STEWART

Philip Charteris Anstruther Stewart, a pioneer petroleum geologist, was drowned, while bathing at Balandra Bay, Trinidad, B.W.I. on January 14, 1923.

He was the son of the late Colonel Charles Edward Stewart, C.B., C.M.G., and was born at Murree, Punjab, India, in 1874 and educated at Cheltenham College and Haileybury, England.

He began his career as an engineer and for four years was engaged in engineering work in England, Germany, and Russia, afterward studying at the Royal School of Mines, London, where he obtained associationships in mining and metallurgy, as well as in geology at the Royal College of Science.

Mr. Stewart went to Mexico in 1901 to undertake certain geological work in the Papantla and Comalteco regions; where wells were being drilled by the Mexican Petroleum and Liquid Fuel Company. He afterward joined the D'Arcy Exploration Company in Persia and at a later date was a member of the Egyptian Geological Survey.

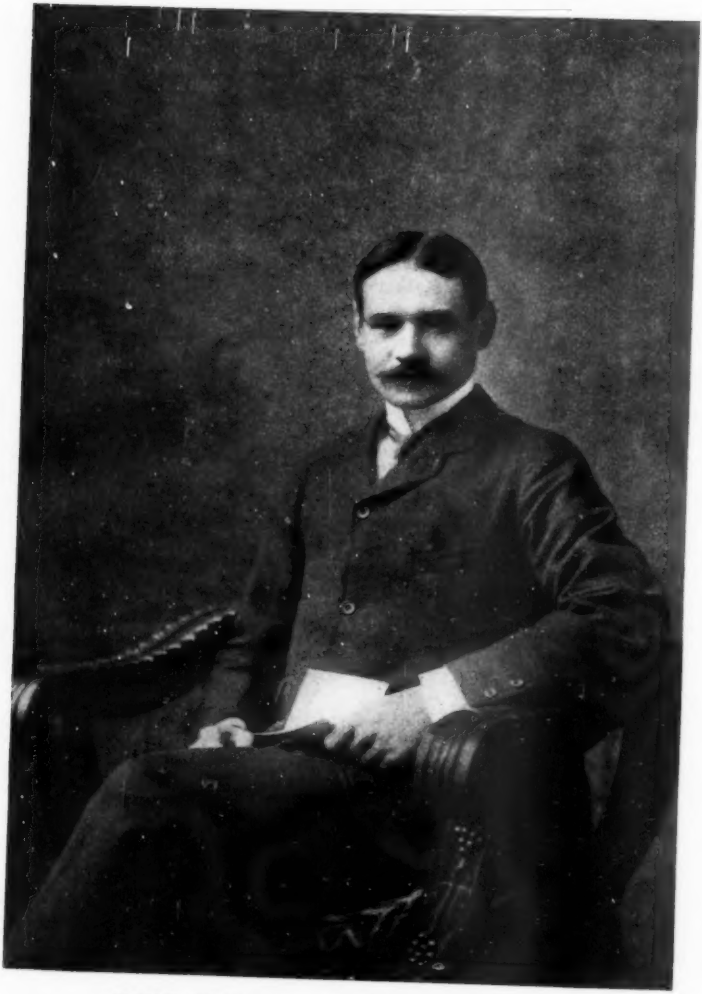
In 1906 he joined Lord Cowdray's firm of S. Pearson and Son, Ltd., and again took up geological work in Mexico. He personally examined much of the northern Veracruz and Tamaulipas area in Mexico, and was better acquainted with the salt dome areas of the Isthmus of Tehuantepec than anyone else in his time. He was not only an able geologist but also a successful administrator. He was for a time manager of the Southern Department of the Mexican Eagle Oil Company, successor to the Oil-fields Department of S. Pearson and Son, Limited.

In 1913 he took up work with the Foreign Department of the Pearson oil enterprises, afterward organized as the Whitehall Petroleum Corporation, and moved his headquarters to London. In this position, in which he actively continued until his death, he became well acquainted with world-wide oil enterprises and visited many prospect areas in foreign countries. He visited the United States many times. In 1908–9 he visited many geological parties in the United States, among them the party working in the Osage under the direction of Carl D. Smith and he had just completed a visit to the Mid-Continent and Gulf Coast en route to Trinidad where he came to his untimely death.

Mr. Stewart was greatly interested in scientific matters, particularly to those relating to geology and to petroleum and mining technology. He was a member of this Association, of the American Institute of Mining and Metallurgical Engineers, the Institute of Mining and Metallurgy, the Institute of Petroleum Technologists, and was a Fellow of the Geological Society, and a Fellow of the Royal Geographical Society.

By the unfortunate and regrettable accident of his death we are the poorer in the loss of one of the best men in our profession, and many of us mourn the loss of a true friend.

E. DEGOLYER



PHILIP CHARTERIS ANSTRUTHER STEWART

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

H. E. GREGORY, of Yale University, is spending the summer in Hawaii. He is in charge of the investigations of the Bishop Museum.

The Pan-Pacific Science congress will be held this year in Australia, at Melbourne, August 13–22.

J. WHITNEY ("JACK") LEWIS, lately in charge of the New England Oil Corporation's Venezuela operations, has returned to the states, and is now located in Tulsa.

JAMES E. HOOVER spent April in Arkansas.

E. M. DAVIS, of Los Angeles, chief geologist of the Shell Co., of California, visited Houston, Texas, in April.

The Southwestern Gas Co., of which HENRY A. LEY is chief geologist, has become interested in the Viking, Alberta, gas field, and will supply the city of Edmonton with gas.

K. D. WHITE is on an extended professional trip to South America.

C. T. LUPTON is chief geologist of the Interior Oil Syndicate, a Denver organization, which plans to operate in northwestern New Mexico.

ADOLPH DOVRE, lately chief geologist of the Sun Co., Venezuela division, has joined the production department of the Sun Oil Co., at Eldorado, Arkansas.

FRANK LITCHENHELD of the Casper branch of the United States Bureau of Mines has been transferred to Washington.

P. V. ROUNDY represented the United States Geological Survey at the Osage sale at Pawhuska, April 5.

JAMES R. PYLE mapped the small fold in section 12, T. 24 N., R. 3 E., Noble County, Oklahoma, on which the Comar Oil Co. has lately completed a "Wilcox" sand well. The geological work was done several years ago for the Marland companies.

BERNARD H. LASKY has moved his offices from the Atco Building to the Tuloma Building, Tulsa.

MAX A. PISHEL is credited with the discovery of the Polhamus pool, Kansas.

ERNEST MARQUARD, vice-president and chief geologist of the New York Oil Co., has returned to Casper, Wyoming, after a trip abroad.

J. WALLACE BOSTICK has resigned as general manager of the Peer Oil Corporation.

T. E. SWIGART is now superintendent of the Petroleum Experiment Station, United States Bureau of Mines, Bartlesville, Oklahoma.

The salt dome recently discovered by S. C. STATHERS, in section 13, T. 17 N., R. 5 W., Louisiana, is known as the "Vacherie" dome, not the "Bashua" dome, as previously reported.

JAMES F. KEMP spent March in Porto Rico and the Virgin Islands, in connection with the scientific surveys of the islands conducted under the auspices of the New York Academy of Sciences.

At the annual meeting of the Okmulgee Geological Society, held on April 6, the following officers were elected: president, R. W. CLARK; vice-president, W. E. BERNARD; secretary-treasurer; O. E. STONER.

C. A. CHENEY, formerly associated with the M. M. Valerius Co., has opened offices at 428 Mayo Building, Tulsa, for the practice of mining and petroleum geology.

T. S. HARRISON, of Denver, spent February in Texas.

MAX W. BALL, of Denver, is president of the Marine Oil Company.

The new field opened in Okfuskee County, Oklahoma, by JAMES H. GARDNER, in section 34, T. 11 N., R. 8 E., is on a fold mapped by BURTON HARTLEY, and detailed by HARRY F. WRIGHT.

R. F. IMBT has returned from Mexico, where he has been employed by the Mexican Eagle Oil Co.

A. F. MELCHER of the United States Geological Survey, spent March in the Burbank oil field, Oklahoma.

W. H. HOBBS and THOMAS C. CHAMBERLIN visited Ponca City in February, to confer with the geologists of the Marland companies on conditions in Mexico.

FRANK R. CLARK, formerly chief geologist of the Wiser Oil Co., is in Washington, completing work for the United States Geological Survey.

A. W. AMBROSE, assistant director of the United States Bureau of Mines, in charge of leasing operations on federal lands, has resigned, and has joined the executive staff of the Empire Gas and Fuel Co., at Bartlesville.

BEN BELT, of Tampico, was in Houston, Texas, in May.

C. T. LUPTON, formerly consulting geologist for the Mutual Oil Co. and allied companies of Denver, has opened an office at 1029 First National Bank Building, Denver, Colorado, as petroleum geologist.

T. S. HARRISON, on February 1, 1923, became consulting geologist for the Mutual Oil Co., and will also maintain his office as petroleum geologist, 706 First National Bank Building, Denver, Colorado.

E. RUSSELL LLOYD is to be chief geologist of the Marine Oil Co., with headquarters in Denver, Colorado. Mr. Lloyd was formerly with the United States Geological Survey, and later with the Sinclair-Wyoming Oil Co. For the past two years he has been chief geologist of the Mid-Kansas Oil Co., with headquarters at Mineral Wells, Texas.

REX RYAN is now with the Marland Refining Co., in Oklahoma.

HASTINGS MOORE is now chief geologist of the Skelly Oil Co.

H. W. C. PROMMEL, for the past five years with Fisher and Lowrie, of Denver, has opened an office as consulting engineer and geologist at Room 526, First National Bank Building, Denver, Colorado.

J. M. DOUGLAS is now employed exclusively by the Union Oil Co. of California, directing that company's geological work in the Rocky Mountain states from his office, 605 E and C Building, Denver, Colorado.

C. B. OSBORNE, chief geologist of the Homestake Exploration Co., Great Falls, Montana, is spending several months in southern California. Address care of Raymond G. Osborne, Marsh-Strong Building, Los Angeles.

J. M. SICKLER, formerly with the California Co. at Billings, Montana, is now with the Union Oil Co. of California, address Union Oil Building, Los Angeles.

E. A. FROYD, the Midwest Refining Co's resident geologist at Salt Creek, is representing Natrona County in the lower house of the present Wyoming legislature.

L. R. VAN BURGH, former associate of C. T. LUPTON, and geologist for the Ute Petroleum Co., Plateau Oil Co., and other companies in Denver, is now valuation engineer, Income Tax Unit, Room 5010 Interior Building, Washington, D. C.

M. E. CARPENTER, formerly with the Roxana Petroleum Corporation at Ardmore, is now engaged in consulting work at Lindsay, Oklahoma.

A. S. CLINKSCALES, formerly with the Sinclair Oil and Gas Co., is now engaged in consulting work in Tulsa.

W. J. MILLARD, of Tulsa, is working in Kansas.

DAVID DONOGHUE, who has been engaged in consulting geological work in Fort Worth for several years, has moved his office to Houston.

G. L. ELLIS, of Snowden & McSweeney, spent March in Oklahoma. His permanent address is Duncan, Oklahoma.

A. C. RUBEL represents Snowden & McSweeney in northern Mexico.

A. C. BIERMAN spent February in San Francisco where he is associated with ARTHUR EATON.

JON A. UDDEN, of Tulsa, spent February and March in Washington.

J. F. HOSTERMAN represents the Amerada Petroleum Corporation in the Tonkawa field, Oklahoma.

CARL D. SMITH is drilling a well west of Mannford, Oklahoma.

R. A. BIRK, is credited with the discovery of the Doyle field, southern Oklahoma.

G. R. HENSEN, of the Roxana Petroleum Corporation, has been moved from Graham, Texas, to Tulsa. L. L. LOOKABAUGH has been transferred from Hewitt to Graham.

F. W. DE WOLF has resigned as state geologist of Illinois to accept a position as chief geologist of the Humphreys-Fohs interests with headquarters at Dallas, Texas, in the Great Southern Life Building.

L. F. RUSS is in New York City.

ROBERT REED is geologist for the Indiahoma Oil Co., of Okmulgee.

G. TEFFREYS has opened an office at 908 Russell Building, San Antonio, Texas.

W. D. GRAY is part owner in the new Wilcox sand well in sec. 14, T. 22 N., R. 8. W., Osage County, Oklahoma.

L. A. SCHOLL, chief geologist of the Texas Co., is in South America.

A. F. TRUEX, of Tulsa, resigned from the Invincible Oil Corporation in March.

B. K. STROUD has resigned from the conservation board of Louisiana and has accepted a position in Los Angeles with the National Supply Co. where he will co-operate with the operators on casing and pipe problems.

W. A. WILLIAMS, formerly with the Pierce Oil Corporation, has been in northern Louisiana.

C. E. HYDE is in charge of the work of the Marland Refining Co. in northern Texas.

G. W. LUCAS of the Roxana Petroleum Corporation has been transferred from Duncan to Hewitt, Oklahoma.

PROFESSOR B. KOTO, of Tokyo, Japan, spent last summer traveling in Asia.

L. L. HUTCHINSON has several wells in the Terlton townsite pool, Oklahoma.

G. B. MORGAN, state geologist of Wyoming, has resigned to engage in petroleum work.

LOUIS FRANKLIN is with the Mid-Kansas Oil and Gas Co. at Mineral Wells, Texas.

D. S. HAGER published a paper on "The Oil and Gas Prospects of Iowa" in the *Oil and Gas Journal* for March 1, 1923.

C. D. JOHNSON spent last summer in Montana. He can be reached at the Pacific Finance Building, Los Angeles, California, care of DORSEY HAGER.

J. T. KUPFERSTEIN, formerly with the Texas Co. in Venezuela, spent the winter in New York City.

RALPH ARNOLD spent February in New York City.

F. G. CLAPP, and J. O. LEWIS were engaged during March and April in mapping Teapot Dome for the United States Senate committee on oil investigation.

CHESTER NARAMORE spent the winter in New York City.

THERON WASSON, chief geologist of the Pure Oil Co., was in Venezuela during the spring.

C. J. WOHLFORD represents the Rycak Oil Corporation at Corsicana, Texas.

EARL W. HUMMEL is located at 837 Mayo Building, Tulsa.

GEORGE E. BURTON is geologist for the Humble Oil and Refining Co., with headquarters at Holdenville, Oklahoma.

C. R. SCHROYER is in charge of the Roxana Petroleum Corporation work at San Antonio, Texas.

R. A. RANK is with the Texas Co. at Shreveport, Louisiana.

JOSEPH A. CUSHMAN and W. J. A. M. VAN DER GRACHT have returned from an examination of properties of the Marland Companies in Mexico.

FRANK A. HERALD has resigned from the Agwi Co., and is organizing an oil company in Tulsa.

BAILEY WILLIS is in Chile investigating the causes and effects of the recent disastrous earthquakes, in the hope of perfecting knowledge by which methods may be devised of forestalling their effects. Dr. Willis will co-operate with the Seismological Institute of Chile of which Dr. Montessus de Ballore is the head. The Carnegie Corporation of New York is providing funds for the study.

HARVE LOOMIS has been engaged in professional work in Kansas.

K. C. HEALD attended the Osage sale at Pawhuska, Oklahoma, in January, on behalf of the United States Geological Survey.

STANLEY C. HEROLD is now at 26 West Fifty-first Street, New York City.

F. B. TOUGH was in California in February.

W. C. MENDENHALL and A. F. MELCHER of the United States Geological Survey visited Tulsa after the Shreveport meeting. Mr. Melcher is endeavoring to arrange for the taking of a core of the entire thickness of the Burbank sand, for use in his porosity studies.

ROBERT H. WOOD has been working in the Texas Panhandle.

LOUIS ROARK has resigned from the Roxana Petroleum Corporation and is in consulting practice at Okmulgee.

CALVIN MOORE of the Coline Oil Co., visited Ardmore, Oklahoma, in February.

T. H. KERNAN resigned from the Mexican Eagle Oil Co., and is now with the International Petroleum Co., on the Isthmus of Tehuantapec.

IRVINE PERRINE of Oklahoma City was in New York in January.

HARRY YOUNKMAN is now with the Roxana Petroleum Corporation at Ardmore, Oklahoma.

RALPH B. ROARK is in charge of the Comar Oil Co's field work at Tonkawa.

J. M. ARMSTRONG is in charge of the core drilling work of the Comar Oil Co., in Kay County, Oklahoma.

L. G. WELSH is now president and general manager of the Duquesne Oil Co., with offices in the Atco Building, Tulsa.

E. L. ICKES, formerly with the Mexican Eagle Oil Co., in Mexico, and later with the Whitehall Petroleum Corporation in London has resigned from the Cowdray interests, and has opened an office as consulting geologist in the Title Insurance Building, Los Angeles, California.

SIDNEY POWERS, of Tulsa, attended the meeting of the American Institute of Mining and Metallurgical Engineers in New York, and presented a paper on "Oil Development in Oklahoma, 1922."

J. M. SANDS is head of the new department of statistics and economics of the Phillips Petroleum Co., as well as chief geologist.

PAUL MC INTYRE has become head of the land department of the Phillips Petroleum Co., Bartlesville.

E. F. SHEA is now associated with SAMUEL J. CAUDILL.

HARRY H. NOWLAN is now associated with ROBERT M. GALER, operating in Arkansas.

E. DE GOLYER is chairman and W. R. HAMILTON is secretary of the American Institute of Petroleum Technologists Division of the American Institute of Mining and Metallurgical Engineers.

R. P. MCLAUGHLIN, formerly state oil and gas supervisor of California, has opened offices in Los Angeles in association with J. E. Elliott and F. C. Merritt. Address, 901–5 Wright and Callender Building.

FRANK CARNEY, who has been at the head of the geological department of the National Refining Company for five years, and W. M. Plake, formerly with the Skelly Oil Company, have been put in joint charge of the operation of the entire producing end of the National Refining Company's business. Their headquarters will be located at Eldorado, Kansas.

During the Spring Quarter of 1923, DR. KENNETH C. HEALD, of the U. S. Geological Survey, geologist in charge of the section of geology of oil and gas fields, has been giving a course of lectures on petroleum geology at the University of Chicago.

A temporary office has been established by the Department of the Interior at 212 Griffin Building, Smackover, Arkansas, for use by the Bureau of Mines in its study of subsurface and operating conditions in the Smackover oil field. P. S. HAURY and R. B. KELLY, of the Bureau of Mines technical staff, will remain at Smackover most of the time until the field work for the proposed report on conditions in the district is finished. This report will be published as a *Bulletin of the Arkansas State Bureau of Mines, Manufactures and Agriculture, Little Rock, Arkansas.*